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FOREWORD.

The following series of lectures represent the effort of the Philadelphia College of Pharmacy and Science to contribute to the educational welfare of the community at large by means of popular scientific discussions.

The lectures were delivered to large audiences by members of the Faculty of the institution and were abundantly illustrated by experiments, lantern slides and specimens. They were subsequently broadcast from several Philadelphia radio transmitting stations.

Given in a form which is simple and understandable they are of particular value to those who are interested in scientific subjects in general and they are not without value to persons who are technically trained along particular lines.

The pleasing reception afforded these lectures prompted this compilation, which THE AMERICAN JOURNAL OF PHARMACY generously undertook, thus making possible the low price at which the book is released.

CHEMISTRY AS AN AID IN THE DETECTION OF CRIME.

By Henry Leffmann, A. M., M. D.

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In treating this subject, the scope of chemistry must be extended to include several accessory methods, especially some that might be in strict classification assigned to physics. Physicists, however, are but rarely called into consultation in legal actions, except in connection with those concerning patents. Chemists, of course, are also frequently called on to testify in patent litigation, but the present study relates wholly to the service of chemistry and its allied methods to the detection of crimes and misdemeanors. In civilized countries, at the present day, the commission of crime is an offense against the state, rather than against the person. The theory is that the state guarantees to each citizen equal protection of the law, and, therefore, must enforce, against any one who infringes such guarantees, the punishments provided.

Chemistry came early in recognition as an important, in fact, indispensable, aid to the detection of many forms of crime, but especially in the detection of poisons. Toxicology has for a long while been the special field of the chemist. The word, by the way, comes from a Greek word meaning a "bow," the weapon used by primitive man. The connection between a bow and poison lies presumably in the use of poisons on the point of the arrow, and thus "pharmakon toxicon," "arrow poison," came to be applicable to all forms of poisons. As chemistry was for many centuries pursued in a somewhat haphazard manner, a systematic treatment of it or of its practical applications was not possible. Notwithstanding the long use of poisons for criminal purposes, the founder of the modern science of toxicology may be considered to be Mathieu J. B. Orfila, a Spaniard by birth, who was born in 1787, the year in which the Convention assembled to frame a Constitution for the United States. His book, "A Treatise on Poisons or General Toxicology," published in French before he was thirty years of age, laid the foundation of a systematic development of the subject.

The great advances made in methods of reseach and in the precision and accuracy of chemical and physical procedures, have given to toxicology a much greater scope and greater exactness, and it will

be the purpose of this lecture to indicate some of the features of the present procedures. While the detection of poisons is still one of the main features of the chemist engaged in aiding the police and the courts, other questions of importance have arisen, among which is the detection of blood and the determination of the animal from which derived. The modern control of foods and beverages has multiplied greatly the applications of chemistry, and compelled much research and investigation. Crime of all kinds, from murder to petty theft, manifests a good deal of ingenuity and resource, and it is not left to the chemist to perfect a process and then rest quietly in the employment of it. Offenders of all grades can also employ scientists, and hence the work of the public chemist is a sort of a game of hide and seek. A process for detection of a certain poison or adulterant becomes known; those who have criminal intent can frequently find either a substitute which is satisfactory for their purposes, but does not respond to the tests for the original substance, or they can mask the original substance so that the standard test fails. The chemist may be said to be "still achieving, still pursuing," and he is constantly discarding processes either because better ones are available or because the ingenuity of law-breakers has changed conditions.

The scope of this lecture does not allow of more than a glimpse at the many applications of chemistry in the service of the law, and hence a few instances of striking character will be presented, and even these can only be given brief description.

At the present day, the chemist cannot dispense with the use of the microscope, which though a physical instrument has taken so prominent a place in the chemical laboratory as to have become a part of that equipment. The microscope has long been used in the detection and distinction of blood-stains. For many years a great reliance was placed on the form of the blood corpuscles, which are materially different in the different classes of animals, but for the higher animals, that is, the common domestic and wild mammals, the form (shape) is about the same although some difference in size is noted. The blood of birds, reptiles and fish shows elliptical corpuscles, while those of mammals are round, but since, in cases of blood-stains, it is possible that some common four-footed animal may have been the source of the blood, a specific distinction of human blood is greatly to be desired. For a long while this was impossible, but a test, known as Bordet's test, is now applicable.

This usually is carried out as follows: A small amount of human blood deprived of fibrin (the clotting material) is injected into the blood of a rabbit, at intervals of four days, until two fluid ounces have been introduced. After about ten days, the animal is bled, the blood serum introduced into sterile tubes and kept for use. In applying this test some of the solution of the stain is mixed with a minute amount of the prepared serum and the mixture kept at 37° C. If human blood is present, a turbidity will be produced which in a few hours will become a flocculent precipitate. The test liquid prepared as indicated gives no reaction with any of the animals common in temperate climate, but it does react with the blood of some of the manlike apes.

A general test for blood is with tincture of guaiac resin and hydrogen peroxide which gives a blue tint. Hawk has found that if the sample to be tested is boiled for 15 to 20 seconds all materials that stimulate blood are so altered that they no longer give the color, but blood preserves its property. Many years ago a man on trial for murder attempted to account for some blood stains on his clothing by saying that he had been carrying some recently killed chickens, but the corpuscles of the stains showed clearly that they had come from no such source as alleged.

One of the most satisfactory methods of identifying substances is by means of their crystalline form. When the crystals are large, as they commonly are in natural minerals and in substances manufactured in large quantity, inspection with the unassisted eye suffices, but in many cases, crystals are very minute and microscopic examination is needed. At the present time, the appliances for such examinations have been brought to a very high pitch, among other methods being modifications of light. Several such modifications are now familiar. The simplest is making a change in the direction of the light as it falls on the object. In this way differences in the surface are made more evident. Another method is by means of colored screens. Polarized light has been of much value. Recently, much valuable information has been obtained by the use of rays of light that are invisible to the human eye, but which have a strong effect on a photographic plate. Some examples of these methods will now be given.

Among the substances which have long been used in criminal poisoning is arsenic. This occurs usually as a white powder, some-

what gritty, and but slightly soluble in water and common liquids. Under the microscope it is seen to consist of brilliant crystals showing more or less triangular faces. The size of these crystals differs somewhat according to the method of manufacture. Owing to the slight solubility of arsenic in the fluids of the body, portions of it may remain for hours in the stomach without losing their distinct crystalline form.

In a case tried in Philadelphia many years ago, several grains of arsenic were found in the stomach of a woman, who had died under suspicious conditions. Her husband was tried for poisoning her, and the defense alleged that she had been taking a trituration of arsenic as a complexion improver. Homœopathic triturations of
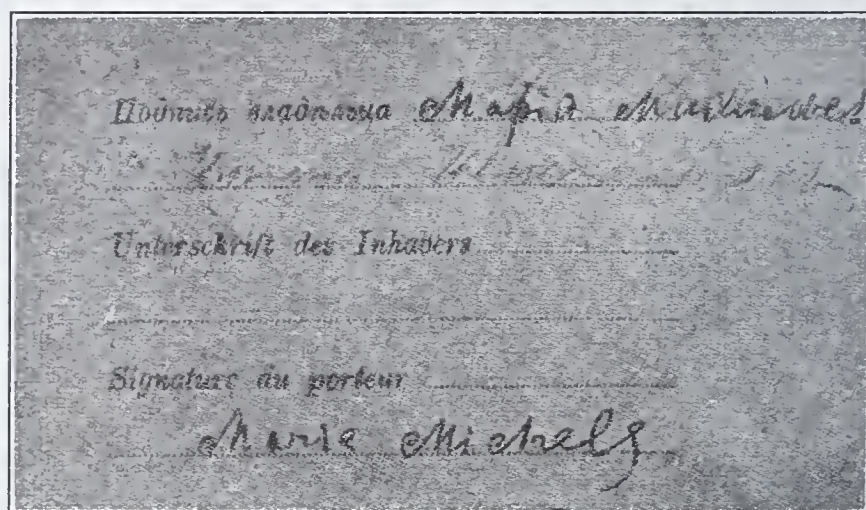
Erasures made more distinct by using color screen.

arsenic were found in the house, but the arsenic in the stomach was in distinct crystals, and it was thus shown that other arsenic had been used. The prisoner was convicted and hanged, and subsequently the attorneys for the defense admitted the truth of the expert's contention.

In the Mary Stannard case, tried in Connecticut, the defense alleged that the arsenic found in the stomach was part of that contained in a package that had been bought for killing vermin infesting a barn, but it was shown that the proportion of crystals of a certain kind was very different in the sample from that in the stomach. The testimony, however, in this case did not convince the jury.

The manufacture of chemicals on the large scale may not be carried out in the same way in different establishments, and hence, it is sometimes possible to determine the specific source of a substance. In this manner, it was found a number of years ago that two large

establishments in Philadelphia produced distinctly different forms of bismuth subnitrate. There was no evidence that one product was inferior, but merely that some difference in the procedure of manufacture caused the formation of somewhat different crystals.

Adulteration of food and drugs is a very extensive and frequent form of crime. The discovery of such adulterations is now the regular business of hundreds of chemists, and much literature is annually published relating to the subject. In this sketch only a few items can be presented. Naturally, the substitution of cheap materials for dear ones is a common form. In this way cheaper starches, such as corn starch, are substituted for arrow root starch; alum is substituted for cream of tartar in baking powders; vegetable and animal fats are substituted for butter; glucose is substituted for cane sugar. The detection of these and similar adulterations requires an elaborate equipment and a thorough training, and the difficulties of the chemist are seriously increased by the fact that new methods of adulteration are continually being introduced, and old methods abandoned. Sometimes an incidental ingredient that happens to be in the adulterating material and not in the genuine substance may serve as means of detection. As an instance of this may be mentioned the use of agar as gelatinizing material in ice cream. Agar is the tissue of a sea plant found in the Pacific ocean. It forms a jelly with water that does not melt at ordinary summer temperature. It happens to be usually accompanied by numerous diatoms, which are minute siliceous skeletons, of characteristic form. As the agar and the food material with which it may be associated can be easily destroyed by strong acids, while the skeletons of the diatoms resist such action, it has been at times possible to detect the addition of sugar by detecting the diatoms.

Crimes of various types are connected with forgery and the alteration of documents. Checks are raised, wills and deeds forged and other misuses made of the arts of writing and printing. A good deal of investigation has been bestowed on the methods of detecting such crimes. Several phases may be presented. Attempts are not infrequently made to manipulate documents so as to indicate a much earlier date of execution than is the fact. Many years ago one of the political parties in Philadelphia, attempted to secure the naturalization of a large number of aliens by means of forged papers alleged to have been taken out several years previously. To give the

appearance of age, the papers were soaked in coffee. This method has been occasionally used. A simple test is the application of a solution of a ferric salt, which, if coffee infusion is present, will produce a black stain. In former times a good deal of stress was laid on the water-marks. These were often somewhat fantastic designs, but in other cases simple designs with dates. The earliest water-mark is very simple and is said to date from about 1300. Of recent years
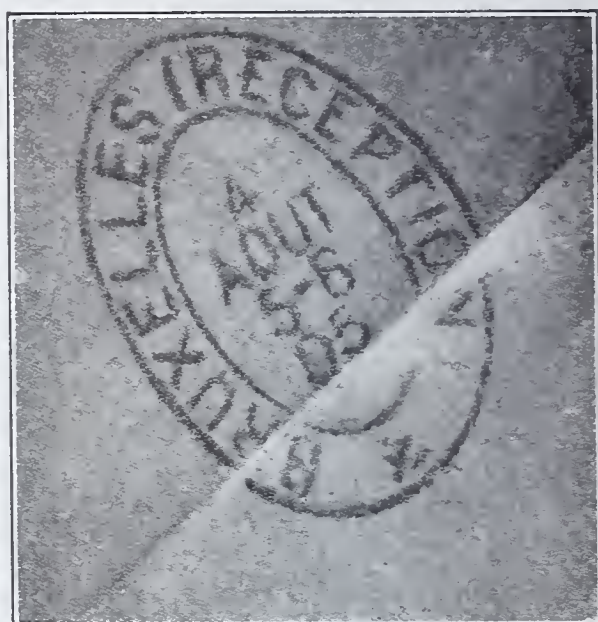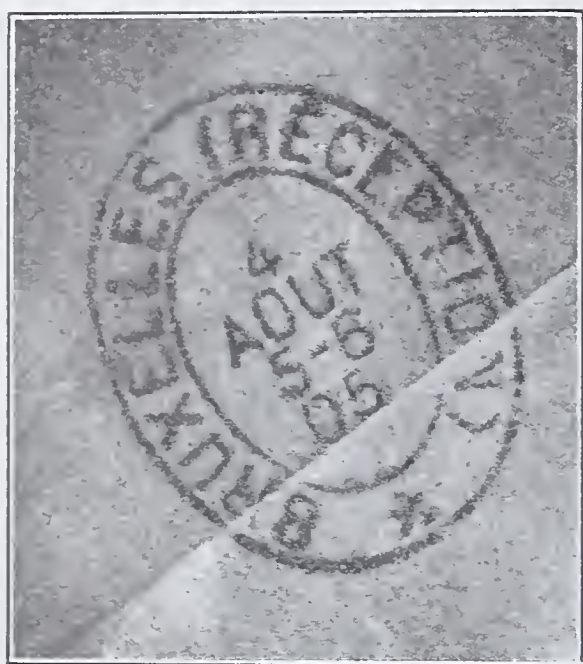
Postmark on envelope which had been opened and reclosed. Left-hand picture under direct light; right-hand picture under oblique light, showing advantage of the latter method.

the introduction of wood pulp and ground wood has given rise to very inferior products, especially for newspapers and cheap books. Sometimes news paper contains very little true pulp and hence early becomes yellow and very brittle.

The detection of such inferior materials is often very important, and chemical and microscopical methods are employed. The several fibres used in paper-making have distinct characteristics and, in addition, ground wood gives distinct colors with certain solutions. The detection of ground wood might serve to show a fraudulent document, since if a deed or other legal document purported to have been drawn at a date previous to the use of such wood was found to contain such material, the fraud would be evident.

The alteration of checks is one of the most serious troubles that business men have. In spite of much ingenuity that has been applied in preventing these frauds, cases are constantly occurring, although it is claimed that lately efficient methods have been devised.

In former days merchants were content to write their checks on plain white paper, but roguery is now too common, and checks are printed on safety papers. Photography has been successfully applied to the detection of alterations and forgeries. By the use of color screens and special forms of light, the texture of the paper and the detail of the writing and erasures can be brought out often quite vividly.

The substitution of artificial colors for natural colors, especially in the preparation of fruit juices, syrups, jams, jellies and soft drinks is a very frequent form of adulteration. The methods of detection in these cases are purely chemical, principally by the use of dyeing of woolen or silk fabrics. Natural colors, at least, of the common fruits and flowers, do not dye very firmly, while artificial colors do. For the detection of coloring in milk, butter and other milk products special tests are employed.

The investigation of crime involves several distinct features. The psychologic phases of human action must be taken into consideration, and, in many cases, scientific investigations are not applicable, but on the other hand chemistry and its closely allied sciences are of great use in indicating the exact conditions under which crime has been committed.

It must, however, be borne in mind that the work of the chemist is not always in the direction of positive results, or of securing conviction for crime. In many cases the laboratory fails to solve the problem submitted, and in others finds results contradictory to those that have been assumed. The world hears less of such cases than of the affirmative ones, but failures are often very instructive. Very often, popular clamor and mistaken inferences lead to investigations which ultimately show that the charges are without foundation, but sometimes the contradiction does not get the currency that the original assertion did. During the late war, statements were made that powdered glass was found in certain food articles supplied to the camps. Naturally, much indignation was aroused, for such admixture could only be the work of a deadly enemy to the nation. The matter was dropped, but the general public has not heard the outcome of the scientific investigation. In at least one case it was found that the material supposed to be powdered glass was really crystals of ammonium magnesium phosphate, formed through some chemical change that had occurred in the materials. In another case a sample of grape jelly was submitted to Dr. LaWall, on account of

brilliant particles scattered through it, the person who brought the sample being convinced that these were powdered glass. Analysis showed them to be crystals of cream of tartar, a constant ingredient of grape-juice, which had crystallized out. The client, however, was not satisfied with the analyst's statement until a few of the crystals were dissolved in boiling water.

Finger marks of accused person taken respectively from a bottle and from a menu card, showing identity.

Chemists who do work for physicians meet with many instances of false claims. Red stains are alleged to be blood; fragments of common stones are submitted as calculi and lots of other fakes are practiced. Those who are engaged in industrial work, such as the analysis of ores and minerals, are constantly meeting with faked minerals, which have been submitted to boost some mining or manufacturing scheme. "Fool's gold" is an old name for an iron-containing mineral which has a bright gold lustre and has deceived many a searcher for mining investments.

[The illustrations are taken from Wolf-Czapek's *"Angewandte Photographie."*]

CORN AND ITS PRODUCTS.

By Freeman P. Stroup, Ph. M.

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Corn is a common Teutonic word, meaning originally a small, hard particle or grain, as of salt, sand, gunpowder, etc. Later the term came to be applied to small, hard seeds (barleycorn, peppercorn, etc.). In agriculture it is usually applied to the seed of cereal plants, and has often been understood locally to mean that kind of cereal which constituted the leading crop of the district, *i. e.,* in England, wheat; in Scotland, oats; in the United States, maize (Indian Corn).

Corned, as applied to meat, meant originally meat (beef generally) preserved by the use of salt in grains or "corns." At present the term applies to meat preserved by the use of solutions of salt.

Corn, as applied to the toe variety, is derived from the Latin "cornu," meaning horny, though not all toecorns are horny.

Indian Corn, Zea Mays, seems to be unknown in the native state, but is probably indigenous to tropical America. Small kernels have been found in ancient tombs of Peru. By some it has been thought to have come from Asia and is said to have been carried by the Arabs into Spain in the thirteenth century. A drawing is said to have been found in a Chinese work dating back to 1562, seventy years after the discovery of America by Columbus. It is not figured on Egyptian monuments, nor was any mention made of it by eastern travelers in Asia or Africa prior to the sixteenth century. Humboldt and others do not hesitate to say that it originated solely in America, probably in Mexico, where it had been extensively cultivated for many years before Columbus' appearance on this side of the Atlantic Ocean. He found natives of the West Indies eating cakes made from the new grain which they called "mahis." Pizarro found the Peruvians using it for food and for making an alcoholic beverage. The Pilgrim Fathers found a cache of it back of Plymouth Harbor.

Botanically speaking, corn belongs to the grass family (order of Gramineæ) and is of many varieties, more than 2000 named varieties having been catalogued. These may be roughly grouped

under five heads: the *Pop-Corns* (Zea Mays everta); the *Dent Corns* (Zea Mays indentata); the *Flint Corns* (Zea Mays indurata); the *Soft Corns* (Zea Mays amylaceæ); the *Sugar Corns* (Zea Mays saccharata), commonly called sweet corn. *Broom Corn,* the tops of which are used in the manufacture of brooms, belongs to a different class of grasses and will not be here considered.

Depending upon the variety, the weather conditions, the nature of the soil, the amount of cultivation, and other factors, corn grows to a height ranging from a few feet to twelve feet or more. Fabulous statements have come out of certain sections of the Middle West as to the height to which the plant has grown. The diameters of the stalks vary with the height, and the relative closeness of the plants in the field.

The flowers are of two kinds, the staminate or male flowers constituting what is commonly known as the tassel, and the pistillate or female flowers and their supporting stem and sheath constituting the ears. On any given stalk the staminate flowers mature first and shed their pollen before the pistillate flowers are ready for pollination. This prevents inbreeding and explains why isolated stalks fail to bear grain on the cobs. The tassels are borne on the ends of the stalks, the ears in the axils of the leaves. The number of ears on a stalk varies from one to three, rarely more. The pollen from the tassels is scattered by the wind and fertilizes the ears on neighboring and, sometimes, quite distant stalks whose pistils, collectively called "Corn-silk," are ready for pollination. If pollen grains come in contact with all the fibers of silk on an ear the embryo grains attached to the lower ends grow and we have a so-called "well-filled ear." In order to ensure well-filled ears corn should never be planted in single rows but, rather, in plats, or "patches."

Some varieties of corn mature in two months from date of planting and some require as much as seven months. The nature of the soil and, particularly, the climate have much to do with the rapidity of maturity. Corn can be grown in the Tropics from the sea level to several thousand feet above sea level; it can be raised in the middle and south of Europe, but not in England, with any chance of profit. It is extensively grown in India and in the United States, and constitutes the most common crop of South Africa, where it is known as "mealies" and furnishes the chief food staple of the natives. It thrives best in regions where the rainfall annually averages around 30 inches, or in

sections which can be frequently irrigated. All other things being equal, it thrives best when there is a succession of hot nights during the height of the growing season, the rate of growth often being so rapid that one "can almost see the corn grow." It has been estimated that 300 pounds or more of water are required to produce one pound of dry matter in the corn stalk.

Closely planted, either broadcast or drilled, corn makes an excellent forage crop. Special varieties which grow rankly to form stalk and leaves, and known as ensilage corn, are widely cultivated, the stalk cut while still green and full of sap, stored in tall structures known as silos, where it undergoes fermentative changes, and from which it is fed to live-stock during the winter months when pasture is not available. The yield may be as much as 80,000 pounds to the acre. Where a silo is not available for storage the so-called "sowed-corn" is cut while still green and cured much as grass is cured for hay, and stored in the same way as hay is stored.

When corn is grown for the grain it is to yield it is planted in so-called "hills," three to five kernels in a hill, the hills 3½ to 4 feet apart in rows about the same distance apart; or the kernels planted at intervals of about 9 inches in rows, the rows being 3½ to 4 feet apart. Some growers plant only one or two kernels in each hill. Too close planting makes for small ears, too thin planting is a waste of ground and makes often for imperfect pollination. The seed-bed should be well prepared by deep plowing and thorough working to make it possible for the roots to penetrate deeply to give firm anchorage to the stalks and to provide abundant storage for moisture, as well as to prevent too free evaporation of the moisture. All other things being equal, the more thoroughly and frequently the soil between the rows is loosened the better for the growth of the crop, not only as a means of keeping down weeds which impoverish the soil, but also as a means of destroying the capillarity of the top soil and thus preventing evaporation of the moisture stored in the lower layers.

Pop Corn Group.—To this group belong a number of varieties which yield kernels which, when mature, are small, rounded or elongated, hard, smooth, generally white to yellow, sometimes red to purple. When these are heated to about 150 degrees Centigrade (302 degree Fahrenheit) they explode, forming a very much enlarged, irregular, white mass in which the starch grains are no

longer recognizable under the microscope, they having been ruptured in the popping process. The explosion of the starch grains is materially influenced by the water content of the grain, the popping proceeding most satisfactorily when the kernel contains 10 to 12 per cent. of moisture. This explains why corn of this kind which has been stored in a warm dry place does not pop well.

Sugar Corn Group.—To this group belong many varieties which yield grain in which the sugar content is more or less highly developed, as much as 8 per cent. in some varieties when in their prime, though much lower in others. The quicker-maturing varieties ("Early Corn") are usually less sweet than the slower-growing varieties ("Late Corn"). Sweet corn is usually eaten while in the unripe state, while the starch is still soft and the sugar content is at its maximum. The sugar which is in the kernel while on the stalk rapidly disappears after plucking the ear, and particularly after the removal of the outer leaf covering or husk; hence the corn should be cooked within a very short time after its removal from the stalk, if its greatest sweetness is to be enjoyed. People who get their sweet corn from city markets or from street peddlers do not realize what the owner of a kitchen garden enjoys in the corn line.

A great deal of sweet corn is made available for winter use by (a) drying in the sun or by aid of artificial heat the uncooked or partly cooked kernels, (b) modern dehydrating processes, and (c) canning processes.

The matured kernel of sweet corn (fit for planting) may be smooth and rounded or very much shrunken and wrinkled, the sweeter the corn the more wrinkled, usually, the seed. Most varieties yield a white seed, some yellow, some red to purple. There are hundreds of named varieties, but the differences between the characters of some are very slight.

It is interesting to note the arrangement of the kernels on the cob, as the grain support is called. Generally they are in rows running lengthwise of the ear, sometimes spirally, and sometimes not in rows but arranged very irregularly. The number of rows is generally even (the author has never seen an ear with an odd number of rows of kernels, nor has he ever met a person who could state positively that he or she had seen such an ear). The minimum number of rows ever seen by the author on any one ear was eight and the maximum twenty, though some authorities state that some vari-

eties yield ears containing twenty-four rows. The number of ker-
nels in a row varies very greatly, some so-called "nubbins" having
only a very few, while fully developed ears may have fifty or more.
An ear of fourteen rows of forty kernels each (an average sized
ear) is thus seen to hold nearly 600 kernels, and when this number
is multiplied by 3, the number of ears frequently found on a single
stalk the result is so much greater than the biblical "sixty to a hun-
dred-fold" that Indian Corn could not, by any possible stretch of
the imagination, have been the grain referred to in the "parable of
the sower."

Field Corn.—This is a name frequently given to certain varieties
of corn whose ears are allowed to come to maturity and the fully
ripened grain is desired. There are several types of field corn, the
grain from each type having properties which adapt it for some
special purpose or purposes.

Zea Mays amylaceæ, which yields a rather soft grain, is largely
cultivated in the Southern States, and plays a very important part in
the daily dietary of the population, particularly of the poorer
classes, where it appears on the table in some form or other gen-
erally at least once a day. Hominy is generally made from this
variety of corn.

Zea Mays indurata (Flint Corn) and Zea Mays indentata
(Dent Corn, so named because of the dent on the outer end of the
kernel) constitute the chief types of field corn grown in the
Northern and Western States, and constitute the bulk of the an-
nual great American corn crop. The 1921 crop, according to
statistics compiled by the Department of Agriculture, was more
than three billion bushels. Because of extensive drought in much
of the so-called "Corn Belt," this year's crop, as forecasted by the
Department of Agriculture statisticians, will be about 225 million
bushels less. The sweet corn and pop corn crops are not figured
in these estimates. Upwards of a hundred million acres of
ground are annually devoted to corn culture, which means an
average production of thirty bushels per acre.

Harvesting of the Crop.—Sometimes the stalks are allowed to
stand until the grain is thoroughly ripened, when the huskers go
through the fields, row by row, opening the husks, breaking out
the grain-bearing cob. More generally the stalks are cut off near the

ground either by hand-wielded knife or by special corn harvesters, and the stalks collected and arranged in "shocks" and allowed to stand some time for thorough curing before the husking is done. The husking is done by hand, either from the ears previously broken from the stalk, or while yet on the stalk. At one time it was quite a common custom in many localities, particularly among the young people, to hold so-called "husking-bees." The amount of corn actually husked on such occasions was usually rather negligible, but the fun that was gotten out of the affair was generally "a-plenty." Apples, cider, nuts, pastry were the chief "refreshments," and dancing was often a part of the entertainment. Husking-bees are rarely held in these days, except as friends and neighbors occasionally get together to do for some sick or otherwise disabled person that which he cannot do for himself. On such occasions the social features play only a minor role.

The dried stalks and husks are much used for fodder for cattle (so-called "roughage") sometimes being given in the whole condition, sometimes shredded or cut. Often they are left in the fields over winter and allowed to rot, after which they are "plowed under" in the spring, having some value as a fertilizer. Some of the thin, paper-like, clean inner leaves of the husks were at one time quite a popular filling material for mattresses, for beds, and occasionally some have found use as a substitute for tobacco in the making of cigarettes. And who, among the older people now living who were brought up on a farm, does not remember the delicate(?) flavor of the corn-silk cigarette as smoked "out behind the barn" where the watchful eye of father or mother could not see?

The Corncob, the portion of the ear to which are attached the kernels and constituting 10 to 14 per cent. of the weight of the husked ear, has a variety of uses. It makes an excellent fuel, having a high heat value, the chief drawback to its use being that it burns so rapidly that fires made with it require such frequent attention. It is sometimes used in place of hickory or other hard woods in the smoking of meats. Real corncob tobacco pipes are well known in some sections, tool handles are sometimes made of corncobs. Chemists in the Department of Agriculture at Washington are said to have worked out a process for the making of furfural from corncobs, the furfural to be used instead of formaldehyde in the manufacture of synthetic resins of the Bakelite, Condensite, Redmanol

type. This will conserve the supply of formaldehyde, the methanol from which it is made and the hard woods from which the methanol is made. Furfural is said to be also a possible motor fuel. It has been made from oat hulls and has been selling for about 50 cents a pound, but when made from corncobs the estimated cost will be about 10 ents a pound.

The Kernel.—The corn grain or kernel varies as to size, color, shape and hardness, the variety, the conditions of growth and ripening, the climate and many other factors, each playing a part. By weight it contains, on the average: water, 10.75 per cent.; oil, 4.25 per cent.; protein, 10 per cent.; fiber, 1.75 per cent.; mineral matter, 1.5 per cent.; starch and sugars, 71.75 per cent. It is richer in albuminoids (protein) when ripe than any other cereal, as well as richer in oil; hence flour or meal made from it becomes rancid more readily than flour made from other grains.

Corn Meal was formerly made by grinding corn between stones, bolting to get rid of chaff (bran). Modern milling methods remove the bran and most of the germ (which contains the oil), the resulting product having better keeping properties than the old-time meal. Meal intended for export is being largely made from a degermed grain with the result that much of the prejudice against corn flour has disappeared from European countries where it once existed in a very pronounced form. That was largely why we were expected to eat more corn in this country during the World War, that wheat could be sent abroad to the people who would not eat corn. Much of what had been shipped them had become rancid on the way over, if it was not already so when shipped. Even in normal times corn meal finds its way into many dishes for the American table. It may not be known to many people today that a hundred years or so ago mush and milk was considered a great delicacy, and hotel and restaurant keepers in Philadelphia advertised in the newspapers that on certain days they would have mush and milk on the bill of fare. Because of the lack of agglutinating power of the nitrogenous constituents of corn flour corn bread and similar products are not usually as light as those made from wheat flour, much of the carbon dioxide gas from the leavening agent escaping before baking has far advanced. Incidentally, for the same reason, pie crust and other baked products made from flour containing corn flour are not as

tough and leathery as they often are when made from wheat flour alone.

Much of the corn produced in the United States is not utilized in the making of flour, but is "worked" for the oil and starch it contains. For this purpose the cleaned grain is steeped in water for from three to ten days at a temperature around 140 degree Fahrenheit to soften it, the water being changed frequently to prevent fermentation. Sometimes sulphurous acid is added to the steep water. The steep water, on evaporation, yields a product which, when mixed with other by-products of the industry, serves as a cattle feed.

By means of suitable machinery the softened grain is separated into three parts—the hull, the germ and the endosperm (body). The germs are dried and subjected to pressure in suitable presses to separate much of the oil, the press-cake being afterwards used chiefly in cattle feed. The endosperms are separated into gluten and starch by kneading with water on sieves, the starch and water passing through. The gluten is mixed with the hulls and solubles obtained from the steep water, the mixture dried and sold as gluten feed for cattle. The milky starch liquid is treated with alkali to render soluble any gluten and oil that may be in it, and the starch is afterwards thoroughly washed with water. One bushel (56 pounds) of corn yields about 28 pounds of starch and about one pound of oil.

Corn Oil when properly purified is a neutral bland oil which may be used as a substitute for lard as a cooking oil, and is a good substitute for olive oil as a salad oil. The poorer grades are used in the manufacture of soaps and a rubber substitute suitable for the manufacture of pencil erasers, synthetic shoe soles, and other articles requiring a raw material having similar properties.

Considerable Corn Starch is used in the manufacture of food products, some of it is used as laundry starch, some of it is used in textile industries as the basis of textile dressings, and a great deal of it is converted into dextrine, dextrose and other alteration products.

Dextrine.—In the manufacture of this product several processes are used. In one process the dry starch is heated to about 212 degrees Fahrenheit in revolving drums which are double-jacketed, the space between the inner and outer walls being filled with oil. After the water in the starch is given off there is but little loss; 220 pounds

yield about 176 pounds of dextrine. Dextrine made in this way may be quite brown in color. In another process the starch is moistened with dilute acid before heating. The product is nearly white. In still another process 8 to 10 parts of dried malt are added to each 100 parts of starch, the mixture moistened with water at 70 to 80 degrees Fahrenheit and kept at that temperature for about 20 minutes, or until the mixture becomes quite fluid, when the temperature is quickly raised to the boiling point. After cooling and filtering, the dextrine is gotten by concentrating the filtrate. Dextrine is used as an adhesive in many industries, but particularly as the basis of dressings for fabrics and in the manufacture of mucilages and pastes for gumming paper, stamps, etc. Card board of the finer grades is made by gumming and pressing together sheets of paper, dextrine being the adhesive frequently used. Dextrine is also used for thickening colors for calico and other printing sizes, and in leather dressings and pastes.

Dextrose is a sugar largely manufactured in this country by heating corn starch with dilute acid, generally hydrochloric, formerly sulphuric, until a portion of the mixture when treated with Iodine Test Solution fails to give a blue or red color, neutralizing the acid with sodium carbonate (when hydrochloric acid is used) or lime (when sulphuric acid is used), filtering through boneblack if necessary, and concentrating the filtrate to a thick syrup or solid. When left in the syrupy form the product is usually known as Glucose and consists chiefly of maltose, dextrose and dextrine and some water. This product is used in the manufacture of printers' rollers, candy, shoe polishes and leather dressings, in liquid soaps, in silvering glass for mirrors, in chewing tobacco, in pastes and sizes, for finishing molds in iron foundries, for mixing with cane sugar and cane sugar syrups for table and baking purposes. When concentrated to the solid form it may be used in the manufacture of caramel (sugar-coloring), and for the manufacture of confectionery products. So-called "Corn Syrups" are generally blends of ordinary sugar and commercial glucose syrup, sometimes flavored with vanilla, maple, etc., for special purposes. They do not often contain over 15 per cent. ordinary sugar.

It has been stated that more than a hundred different commercial substances of value in our everyday life may be properly called "Corn Products," but lack of time makes it impracticable to pursue the subject farther at this time.

THE STORY OF GLASS.

By J. W. Sturmer.

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My first impression of a glass factory is still quite vivid. It was years ago, and in the natural gas belt of Indiana. The "works" were located in the open country, and our visit was in the late evening. From a distance we could see the big stacks silhouetted against the night sky. On approaching, we saw the sprawling buildings, brilliantly illuminated inside by the fires in the furnaces. Dark figures were passing to and fro, and to the tune of a weird chant. It seemed uncanny—spooky. Were they elves at play, as Rip Van Winkle saw them in the Catskills—or gnomes of Vulcan performing their rites in a modern temple of Keramaikos?—or humans engaged in some uncommon but prosaic tasks? As we came closer, and as the tune changed to "Annie Roonie" all illusion was dispelled, and we saw men and boys at work, grimy and perspiring, but singing at their toil and exhibiting marvelous skill, for here was in very fact one of the modern work shops of Vulcan, where by the aid of fire men made that transparent igneous rock called glass, which is so intimately associated with the scientific progress of modern times, and which has so fundamentally changed our habits of life.

A Few Fragments of History

Our archeologists, engaged in uncovering very ancient Asiatic ruins, have looked in vain for articles made of glass. Pliny tells us a story of Phoenician merchants—or were they mariners?—who kindled a fire on a sandy beach, on the shore of Asia Minor, using blocks of nitre to build a rude fireplace, and who found in the ashes of their camp fire a transparent, glass-like substance. But the modern glass worker, knowing the high temperature required in the process of making the substance which we now classify as glass, and knowing the difficulty of attaining this high heat in an open camp fire, is forced to the conclusion that if Pliny's narrative has a basis in fact, the substance formed must have had a composition quite different from that of modern glass. The ancient Egyptians, however, as early as 1600 B. C., did make glass beads and glass ornaments, and may have originated glass making, although students of ancient history are rather inclined to hold with Pliny that the discovery of glass happened in Syria.

As the art of glass making developed, glass vessels, such as amphoræ (bottles), drinking cups and vases, were made, and such specimens have been discovered in the tombs of Egypt. The first authentic example of ancient window glass was discovered in the ruins of Pompeii, and the panes were found still securely held in their frames of bronze. Strange to say, this Pompeian glass, on analysis, disclosed practically the same composition, not only qualitatively, but also quantitatively, as the common glass of present-day American manufacture.

But it should be remembered that the windows of very ancient architecture are merely openings, that during the Roman era, glass windows were used to a very limited extent; and that thin sheets of marble, and other translucent rock, were more commonly employed for the purpose. It is accordingly difficult to determine when the glass window, as we know it, came into use. Certainly it is hard to say when such windows became a common feature of dwelling houses. In England, during the Elizabethan period, glass windows were still confined to cathedrals, and to the castles of the nobility. A memorandum of the steward of the Duke of Northumberland, written in 1567—when Shakespeare was a three-year-old boy— suggests that the glass panes of the castle windows be taken out of their frames and stored in safety during the duke's absence, lest they be broken by the storms—a precautionary measure indicative of the rarity and costliness of window glass at that time. Indeed, windows of oiled paper, and of parchment, were still in general use in the latter part of the eighteenth century, even in the city of Paris.

It is interesting to contemplate to what extent the glass window has in recent times influenced the distribution of the human race. How it has played its part in determining the material progress and the industrial supremacy of the nations of the North. Their very modes of living have undergone a change, because of glass, for they have become house-dwellers, and the productivity of their workshops has become enhanced as glass windows made possible activity throughout the year in many industries which formerly were seasonal, and were stopped by bad weather. Indeed, at the present time, the use of glass, in the construction of factories is still on the increase, and seemingly will continue to be until the conventional factory building will have become in very truth a house of glass.

In 1607 the first glass factory was established on American soil, and was located in the primeval forest, a mile from Jamestown. In 1683 glass making had its modest start in Philadelphia. There are now in operation throughout this country three hundred and sixty-odd glass factories, representing all branches of this important industry.

Glass making remained an empiric art for many centuries. Attempts to give it a scientific grounding began about a hundred years ago. In 1882, Abbe, Schott and others, entered upon their fruitful researches on the chemical composition of glass, and laid the foundation for the truly marvelous development at Jena, Germany, which resulted in the production of all kinds of optical glass, and of new types of glass for chemists' use.

The most conspicuous contribution of our country to the development of the industry has been along mechanical lines, and in the solving of engineering problems incident to mass production, although we must not forget that our glass chemists have kept abreast of progress, and that American chemical ware, window glass, and bottles, are equal to the finest products of Europe.

Pottery and Glass

The making of pottery is one of the oldest of arts, and is intimately connected with glass making. History does not tell us— nor will it ever tell us—when man first noticed that the clay under his feet had been baked hard by the rays of the sun, and when, taking a hint from this observation, he first shaped rude domestic vessels out of moist clay and learned to make them more durable by baking them in a fire. All pottery making, to this day, involves shaping water-moist clay, drying and then baking, thus causing partial fusion, with the result that the unfused particles are cemented together. Articles of glass, on the other hand, are shaped from a product obtained in the molten condition, and which on cooling passes gradually through all phases of plasticity.

The predominating constituent of the material used for pottery is clay, while sand is the chief ingredient of the mixture which yields common glass.

How pottery and glass are connected in our story we shall see presently. But what *is* glass?

The chemistry of glass—indeed of ceramics generally—is built about the element silicon, an element constituting about one-fourth

of the earth's crust, but which, because of its affinity for oxygen, is never found in the free state. Elementary or free silicon is a product of a laboratory process. For this reason, silicon was not very generally known until rather recently. It occurs as a brown or black, amorphous powder, or as a black, hard crystalline substance, having a melting point of about 2600° F.

Just as carbon is the keystone of the varied compounds found in the organic world—in compounds which make up vegetable and animal matter—so silicon is the keystone of the compounds of the soil. Sand is silicon dioxide; clay is aluminum silicate; most common rock materials are silicates; the granite boulder, carried to our latitude from its distant parent rock by the glacial drift, is mainly a mixture of silicates. Our food grows forth out of a soil of silicates. If we build our house upon the shifting sand, or build it upon solid rock, we build it, in either case, upon compounds of silicon—unless we happen upon an out-cropping of limestone, which, as is well known, is a carbonate.

And these two elements, carbon and silicon, are closely related chemically. Moreover, just as man has learned to make artificially many compounds of carbon which are not found in plants or in animal organisms, so man has learned to produce compounds of silicon which are not formed in nature's own laboratory.

Glass

Glass is a man-made product—an artificial igneous rock. But like natural rock, it is made up of silicates, and differs from the composite rocks which we know in that the silicates have been fused together to a homogeneous product.

Glass is a generic term, for there are endless varieties, all differing in composition, and in their characteristics and uses.

Common glass is technically known as soda-lime glass, and is made by subjecting to a temperature of about 2000° F. a mixture of sand and lime, or limestone, and soda ash, which is the name given to partially dehydrated washing soda. Let us examine these substances more closely.

The Silica

Sand, as has been stated, is silica, or silicon dioxide, SiO_2, of course contaminated more or less with impurities. If sand be heated in an electric furnace to a temperature of about 3500° F., it will be-

come plastic and cohesive, and may be formed into evaporating dishes, crucibles, or tubing. Such ware now finds extensive use in chemical laboratories, because of its heat-resisting, and heat-shock-resisting properties, and because of its being practically insoluble. The larger articles of silica ware are white or nearly so, opaque, and with a silky lustre, which is due to the imprisonment of countless minute bubbles of air. Complete fusion expels these bubbles and renders the silica transparent. Silica ware, particularly the transparent variety, is also called quartz glass; and when, on prolonged heating, this colloidal silica crystallizes, and loses its homogeneity, we say it de-vitrifies, which means that it loses its glass-like character. Popularly, however, silica ware would not be classified as glass ware.

The Lime

If the lime be subjected to intense heat, it becomes incandescent. It does not, however, fuse at the temperature attainable by furnace fires, as its melting point is above 4500° F. So we say that the lime is *refractory;* and a substance which exhibits this resistance to fusion is technically classified as a *refractory substance.* Lime magnesium oxide, fire brick, and burnt clay generally, are refractory materials, and play an important role in all operations involving the use of high heat.

Silica and Soda Ash

But if the sand—silicon dioxide—which is, as we have seen, difficultly fusible, be mixed with soda ash, and the mixture heated, the sodium salt serves as a "flux," for at a temperature sufficiently high, the silicon dioxide, which is chemically speaking the anhydride of silicic acid, exhibits its acidic property, interacts with the sodium carbonate (soda ash), displaces carbon dioxide, and forms sodium silicate, a fusible, transparent substance, of the appearance of glass, but water-soluble, and for this reason called *water glass.*

Water Glass and Sand and Lime

If now we add more sand, and some lime to the fused water glass, and heat the mixture to a high temperature, the silicon dioxide and the calcium oxide (lime) will also interact, and will form calcium silicate, a substance which dissolves in the sodium silicate to a clear solution. This solution, however, is liquid only at a high temperature, and, on cooling, solidifies to a transparent

solid—a solid solution of calcium silicate in sodium silicate, *common glass*, the soda-lime glass of the glass maker. Fruit jars, bottles, window panes are made of soda-lime glass. And all glass, regardless of its specific composition, is of the character of a solid solution, in which some of the constituents play the part of solvents.

The glass maker does not, however, conduct the process in two distinct steps. He mixes the sand, lime or limestone, and the soda ash—the fire does the rest.

Kneading Clay for Glass Pots

The Glass Furnace

But suppose we had such a mixture to subject to intense heat in our own laboratory. Our first concern would be the selection of a crucible capable of withstanding the high temperature to be attained, and resistive to the chemical action of the substances to be heated. We would probably select a clay crucible. We would be

"inclined" also to enclose our fire in a housing of refractory material, so as to confine the heat as well as possible. In this manner, following the customary laboratory procedure, and without drawing upon our knowledge of practical glass making, we would construct a miniature

Pot Furnace

To be sure, such a furnace, in a modern glass plant, is the product of long experience, and of considerable engineering skill, employed to the end of constructing a furnace specially adapted to the work at hand. It may be large enough to hold a dozen or eighteen pots. And these pots may hold probably a ton or two of glass; but they are merely large crucibles made with exceeding care, of selected clay; and the furnace is a development of the housing which it is customary to build about a fire for high temperature operations.

Modern glass furnaces are either gas burners, or oil burners. If the former, the gas may be natural, or it may be the type of artificial gas known as producer gas, which is essentially carbon monoxide mixed with air.

Prior to the era of gas and of atomized oil, coal and wood were the fuels used. Indeed, the American glass factories of the earlier period were located with a thought to an abundant supply of wood close at hand.

Glass Pots and Glass Tanks.

For common window glass, or ordinary bottle glass, the crucibles or clay pots may be replaced by shallow tanks built of fire clay, some of which are quite large, are so constructed as to furnish glass without interruption from day to day, and are known as continuous tanks. But all high quality glass is still made in clay pots.

These crucibles are of carefully selected clay, which is moistened and tramped to perfect homogeneity by the naked feet of men, just as it was done centuries ago. After the crucible has been shaped, it is kept in a warm room at constant temperature to dry out very slowly, and after having been subjected to "seasoning" for months, it is ready to be "fired" in a furnace adapted for this special purpose, an operation requiring great skill and experience. At nearly white heat it is transferred to its position in the

glass furnace, is glazed with molten glass, and is ready for the "batch," that is, for the mixture of sand, lime and soda ash, previously mentioned. We see now how essential the potter's art is in the glass industry.

Heating the Batch

As the temperature rises, this mixture becomes pasty, gives off water, carbon dioxide and other gases, changes to a sluggish, opaque fluid, which in turn becomes clear, but is now found to be filled with countless bubbles of gas. Continued heating expels these bubbles, and the glass is said to have become "plain." It is now cooled down to proper viscosity to admit of its being "gathered" on a long blow pipe and "worked."

Shaping Glass Pots

The ratios of sand to soda ash and to lime may be varied within certain limits, to produce glass of desired characteristics. Thus, increasing the soda ash lowers the softening point of the glass, while increasing the sand, or the lime, makes the glass harder, and more difficultly fusible. Too much soda ash makes the glass susceptible to action of water. Such glass develops marked alkalinity in aqueous liquids, and may even be subject to "weathering." The ratios of one

hundred parts of sand to about thirty of soda ash, and thirty or thirty-five of limestone, or about twelve of lime, gives a general idea of the make-up of a batch.

Glass being a homogeneous mixture, and not a specific compound, it does not exhibit a definite melting point, but softens very gradually, through a considerable range of temperature, to ultimate liquefaction. And it is this property by virtue of which glass lends itself to manipulation and shaping in so many different ways. Thus, it may be poured out in a molten condition upon a flat surface, and allowed to solidify to a "plate." It may be pressed into a mold by means of a plunger (pressed ware). It may be—if it is hot enough, and soft enough—blown into a bubble like a soap bubble. Or the bubble of glass may be blown into a mold, and thus be given the shape desired.

Plate Glass

Plate glass is made by casting the glass upon a table, rolling it to the desired thinness, and subsequently, after annealing, grinding down the wavy surface until it is quite even. The grinding is accomplished with sharp sand, then with emery, and finally, a fine polish is obtained with jeweler's rouge—which explains why plate glass is free from the waves and imperfections so frequently seen in common window glass.

Common Window Panes

They are made by gathering upon a blow pipe a large portion of the semi-liquid material, ballooning it out by blowing, elongating the large glass-bubble formed, by swinging it to and fro, like a pendulum, and, when it has become sufficiently cylindrical, cracking or cutting off the apex and base and slitting open the resulting cylinder. This is now promptly placed in an oven where heating softens the glass sufficiently to admit of its flattening to a sheet, which is then annealed, and cut to provide the sizes commonly required for windows.

By carefully gauging the amount of glass "gathered," the workman makes either single strength (1/12 inch thick) or double strength (1/9 inch thick) sheets of glass. The amount gathered may be a ball the size of a man's head, and weigh about fifteen pounds. The elongated cylinder formed is about twelve inches in diameter and about five feet long.

Machine-Made Window Glass

Engineering skill has evolved machinery which has made possible the use of compressed air in blowing the glass cylinders. The blow pipe is arranged vertically above a pot of molten glass, so that the end of the tube dips below the surface. Air is now forced down the tube, and the latter is slowly raised, carrying a huge, cylindrical bubble upward, to the height of probably thirty or forty feet, producing a cylinder of this length, and of a diameter of about twenty-four inches. These immense cylinders are then worked up into panes by the procedure previously described.

Cylinders for Window Glass by Compressed Air

Crown Glass

The window panes of ancient manufacture were generally round, and were made by blowing into the "gather," rupturing the resulting globe, and causing this by dexterous twirling, to assume the form

of a disk. These disks, because of the shape of the glass bubble at a certain stage of the operation, were known as "crowns." At a later period the disks were made large enough to admit of being cut into square or rectangular panes. At the present day the use of crown glass is limited practically to the making of microscope slides and cover glasses.

Plate Glass Manufacture

The most striking feature of plate glass manufacture is the transferring of the pot of molten glass to its position above the metal casting table, the tilting of the pot, and the flow of the sluggish, but intensely hot, and brilliant-glowing liquid, as it gradually covers the entire expanse of the metal surface, like a huge mass of hot butterscotch. The thickness of the plate is determined by metal strips fastened to the edges of the table; and a huge roller, passing over the rapidly cooling and congealing glass, irons it out to uniform thickness, which for common window plate is about three-quarters to seven-eighths of an inch.

After the plate has been annealed, it is found to present a wavy surface; but the grinding removes all inequalities, though at the expense of a considerable loss of material, for the finished plate ranges only from one-quarter inch (for small sizes) to five-eighths inch (for the larger) in thickness. For special purposes, as for example for aquariums, counter tops, etc., plate glass may be obtained fully one and a half inches thick. Unground plate, known as rough plate, for skylights and simliar purposes, is in extensive use, and constitutes a considerable portion of the factory output. Plate glass, re-enforced with wire netting, has found extensive use. A modern factory, as has been said, is a house built of glass, with just enough iron work to constitute the frame, and probably some facing of brick or concrete,— and wire glass is specially adapted for such construction. Wire glass is now made by rolling the wire into the plastic glass upon the casting table, although the old-style sandwich glass, made by pressing together two sheets of heated glass, with the wire netting between the sheets, is still on the market. Though the process of making wire glass is seemingly no more difficult than the making of common plate, special knowledge and skill are required to furnish a product which will not crack on heating or cooling, on account of a difference in the coefficient of expansion of the metal and of the glass.

Non-Shatterable Glass

Non-shatterable glass, safety glass, bullet-proof glass, or triplex-glass, as it is called in England, is made by sandwiching a sheet of celluloid, or similar material, between two thin plates, using a special cement, and high pressure, to effect perfect union. Non-shatterable glass will crack, but will not splinter, and is for this reason particularly valuable for automobile windshields, cashiers' windows, and the like.

Pouring Glass for Plate

Figured Plate.

Remembering that glass by skillful heating may be made to exhibit any degree of plasticity, it is apparent that if the roller used in ironing the glass on a casting table carries a design, the plate can be made to present a hammered, rippled, or ribbed, or figured surface. Such glass may not only be valued on æsthetic grounds, but also because in this way the glass becomes virtually a translucent rather than a transparent medium, adapting it for office partitions, and for other uses demanding a medium which will obstruct vision but which will transmit light.

Chipped Glass

Chipped glass, with a configuration on its surface resembling winter's frost, has been on the market nearly twenty years, and is obtained by covering the sand-blasted or ground glass with a coating of

glue, and then carefully heating. As the film of glue shrinks, and hardens, and peels off, it tears loose slivers of glass in fern-like patterns, producing a surface which looks as though it had been coated with frost. A similar result may be attained with a varnish of mastic and sandarac, dissolved in ether and benzene. By repeating the operation (double-process chipped glass), the rough and blasted surface is wholly removed, greatly improving the appearance of the plate.

Actinic Glass

Actinic glass—so called—is a plate glass, plain or wire glass, which has the property of absorbing a large portion of the ultra-violet and the infra-red rays, thus being admirably adapted for warehouses for rubber, dyed cloth, and other materials susceptible to heat and light. Actinic glass is made by the addition to the "batch" of either natural or artificial biotite, which introduces iron, nickel, titanium, aluminum, magnesium and a trace of manganese, into the composition of the glass, and imparts to it the absorptive properties toward heat and light waves for which it is valued. Actinic glass is usually marketed in the form of wire glass, which has the mechanical strength so valuable in factory or warehouse construction.

Glass Etching

The etching of glass depends upon the chemical action of hydrofluoric acid, which decomposes soda-lime glass into silicon fluoride, SiF_4, sodium fluoride, NaF, and calcium fluoride, CaF_2, the glass thus being made water-soluble. While all types of glass may be etched with hydrofluoric acid, there is a great difference exhibited by the different types of glass in their behavior to the etching agent. Thus resistance glass is also more resistive to hydrofluoric acid, and is for this reason more difficult to etch, while flint glass, which is potash-lead glass, is particularly amenable to this treatment.

The procedure involves covering the glass with a varnish which is not attacked by the etching liquor; a mixture of rosin, tallow or beeswax, Venice turpentine, oil of turpentine, and asphalt, serves admirably. The design is traced in the wax-like coating, so as to expose the glass, which is then immersed in the etching bath for the required period of time, and is subsequently washed. Etched graduations may be made more conspicuous by rubbing in a white or colored enamel. In chemical laboratories, barium sulphate, red lead, or carbon black are sometimes employed for this purpose.

Color in Glass and Decolorizing

When a pane of common window glass is inspected edgewise, it is seen, usually, to have a greenish tint. This is due to ferrous silicate, formed from the iron present in the sand, and in the other crude materials used in the batch. This greenish coloration may be destroyed by oxidizing the ferrous iron to ferric iron, a result which is frequently attained by the addition of manganese dioxide. But an excess of the latter gives to the glass an amethystine hue, which is thought to be accentuated in course of time. It is exceedingly difficult, even with our present-day methods of chemical control, to balance the manganese dioxide so accurately against the ferrous silicate as to produce a truly colorless product. and all common glass usually shows "high color"—so called, due to manganese, or "low color," due to iron.

Other decolorizing agents in general use are arsenous oxide, and selenium. In some glass works sand of very high iron content is now successfully utilized because of the skillful use of these decolorizing agents.

It is important to know also that excess of manganese may operate in a purely physical manner, its color tending to compensate for the green of the ferrous silicate. This effect may be illustrated by making a solution of manganous sulphate, which is pink, and pouring it into a bottle of greenish glass, when it will be seen that neither the green of the glass, nor the pink color of the solution, is very noticeable. Indeed, by careful adjustment, the two colors may be made to disappear. Chemists and pharmacists who may have occasion to compare colors of liquids, should always keep in mind the bearing which the color of the glass container may have on the appearance of the contents, and when such comparisons are to be made, glass ware practically devoid of color should be selected.

Varieties of Soda-Lime Glass

Soda-lime glass varies considerably in percentage composition, and accordingly varies in fusibility, resistance to water and to chemicals, varies in mechanical strength, and in other physical properties; and the practical glass maker has learned to produce a soft or hard glass, a quick-setting, or a slow-setting product, indeed, to provide the glass with the particular properties required for use in connection with certain automatic bottle-making machines, or for "hand-work."

Increasing the soda ash in the batch lowers the softening point; increase in quantity of sand or of lime, raises it. But glass high in soda content is more susceptible to action of aqueous liquids. Indeed, common bottle glass will produce decided alkalinity in distilled water, and will quickly develop a brown color in physostigmine solution, which in a resistive glass will remain without change.

Other Types of Glass

The soda may also be replaced by potash, the lime by the compounds of other metals, notably by compounds of barium, lead, zinc and aluminum, and the silicate radical may be replaced in part by borate or phosphate.

The introduction of borates lowers the coefficient of expansion, and thus makes possible the production of heat-resistive ware, which is a product of recent development. Speaking generally, heat-resistive glass is also resistive to chemicals, and has great mechanical strength. It may be pointed out in this connection that the term heat resistive has reference not only to a high softening point, but also to the endurance to a marked degree of sudden temperature changes.

The following makes of resistive glass ware are well known:

Jena chemical glass ware—A boro-silicate glass of sodium, zinc and aluminum.

Nonsol—Boro-silicate of sodium and zinc, with magnesium and aluminum, and traces of arsenic and antimony.

Pyrex—Boro-silicate of sodium and aluminum, with excess of silica and traces of arsenic. (May be obtained arsenic free.)

Libbey—Boro-silicate of sodium, aluminum and lead, with a little arsenic.

Macbeth-Evans—Boro-silicate of sodium, zinc and magnesium, with traces of arsenic, and some antimony.

The Bureau of Standards, in Bulletin No. 107, gives analyses of these products as follows:

Analyses

Ware	Kavalier beaker	M.E.G. Co. beaker	Pyrex beaker	Jena beaker	Jena flask	Nonsol beaker	Fry beaker	Libbey beaker
Al_2O_3	0.14	1.0	2.0	4.2	4.2	2.5	2.7	2.1
Fe_2O_3	0.08	0.35	0.25	0.25	0.27	0.23	0.22	0.44
ZnO	....	5.6	....	10.9	10.9	7.8	3.6	....
PbO	....	....	....	....	....	....	....	1.0
MnO	0.02	0.02	0.01	0.01	0.01	0.01	0.03	0.03
CaO	8.7	0.66	0.29	0.63	0.56	0.79	2.6	0.42
MgO	0.17	4.3	0.06	0.21	0.25	3.4	2.6	0.08
Na_2O	7.1	10.8	4.4	7.5	7.8	10.9	9.8	8.2
K_2O	7.9	0.30	0.20	0.37	0.31	0.30	1.5	0.67
SiO_2	75.9	73.0	80.5	64.7	64.7	67.3	68.6	75.9
B_2O_3	....	3.6	11.8	10.9	10.6	6.2	8.1	10.8
P_2O_5	0.08	....	....	....	....	....	....	....
SO_3	0.20	0.02	....	....	....	....	....	....
As_2O_5	Trace	0.02	0.70	0.14	0.19	Trace	0.18	0.36
Sb_2O_3	....	0.60	....	....	....	0.62	....	....
Total	100.29	100.27	100.21	99.81	99.79	100.05	99.93	100.00

Contrast these analytical data with the analyses of common glass for bottles, window panes, and the like:

	Bottles	Window Glass
Al_2O_3	.5	.1
Fe_2O_3	.3	Traces
ZnO	..	..
PbO	..	..
MnO	..	..
CaO	17	12.4
MgO	.5	Traces
Na_2O	11.2	13.7
K_2O	..	Traces
SiO_2	70.00	71.5
B_2O_3	..	..

A potash-lime glass is more brilliant than soda-lime glass, and is used for table ware, and for artificial gems. Hollow ware of this glass may be distinguished by its clearer "ring" when tapped with a pencil.

Flint glass is potash-lead glass, has more brilliancy than potash-lime glass, and is used for the more expensive types of "cut glass ware." It is characterized by its weight, is rather soft, and easily scratched.

Optical glass varies considerably in composition. It may contain either sodium or potassium, or both, may contain barium in place of calcium, may be an optical flint glass, which means that it contains lead, may contain aluminum, or zinc, may be a silicate glass, or a boro-silicate, or a phosphate. The boro-silicate and phosphate glasses were evolved at Jena in 1883, and are of value because they do not exhibit the secondary spectrum—a discovery which led to the development of the modern microscope, and which thus links up with the extraordinary progress made in biology in recent times.

As has been said, glass may be made to conform to definite specification—within certain limits, to be sure—as to physical properties. The physical properties which are of special significance are, the thermal expansion, tensile and compression strength, elasticity, hardness, specific heat, thermal conductivity, dielectric constant, solubility in water, and in alkaline solutions, refraction, dispersion, absorption of the different wave lengths of light rays, absorption of ultra-violet, and of infra-red rays.

Boron reduces the coefficient of expansion and raises the mechanical endurance. Aluminum increases the compression strength, zinc the tensile strength, both tend to increase the resistance to chemical corrosion.

Lead and barium raise the refractive index. In short, the glass maker has learned to predetermine the properties of the product, by virtue of his knowledge of the properties imparted by the basic and acidic substances available for glass making.

Colored Glass

Reference has been made to the greenish color of common bottle glass, and to the lilac coloration of some window glass, the former due to presence of ferrous iron, the latter to manganese. The tinge produced by an impurity may, of course, be deepened by the deliberate addition of more of the same color-imparting substance; and by experimentation, extending through many centuries, the glass maker has learned to produce glass of practically any color which may be desired. To be sure, the color of the resulting glass may be in decided contrast to the color of the substance added to the "batch." This result may be due to chemical action, and to the production of a new substance, or it may be due to minute subdivision. If, for example, a liberal quantity of bone ash (calcium phosphate) is mixed

with the molten glass, a milk white glass will result, and it will be found to have lost its transparency. In other words, the glass will exhibit the color of the bone ash. If, however, amorphous carbon, which is black, be added in small quantity, the finely subdivided, but undissolved particles, will color the glass light or dark amber—according to the amount used—and the glass will be found to have lost in transparency, but will not prove to be opaque.

So we may conveniently classify colored glass under the following heads:

Color due to suspended matter in rather large particles, incorporated either by direct admixture, or, as in case of certain opal glass, by precipitation on partial cooling.

Color due to colloidal solution or suspension, as in case of elementary carbon (amber), elementary selenium (red), elementary copper (red), elementary gold (red to purple, according to size of particles), elementary silver (yellow).

Color due to silicates which exist in solution—cobalt (blue), manganese (lilac to purple, according to amount used), chromium (green), ferrous iron (light green), nickel (pink to purple, in a potash glass), uranium (greenish yellow).

Not only is the color obtained by addition of certain coloring agents influenced by the quantity employed, but also by the method of treatment. Thus copper salts may yield a blue glass under oxidizing condition, and a red glass under reducing conditions, when elementary copper is formed in colloidal suspension or solution.

When gold glass is removed from the pot, it is devoid of the characteristic ruby color, which develops only on re-heating, and as the minute particles aggregate to form particles of larger size. If the process is prolonged, the color changes to purple and to brown, and eventually, particles of yellow, metallic gold, become visible. Aventurine glass, used as a setting in rings, is made by this process.

Flashed glass is made by overlaying a sheet of colorless glass with a thin film of colored glass. Designs may be cut through the layer of colored glass by the grinding operation as employed in the production of "cut glass." Flashed glass is quite common, and is largely used when conspicuous lettering is wanted for signs or for glass door panes.

Cameos are made from flashed glass, the design being carved out of the uppermost layer, and made to show conspicuously by virtue of the contrast in the colors of the strata.

Iridescent glass is made by subjecting the glass ware while hot to the vapors of certain metallic salts, particularly to those of stannous chloride, strontium nitrate, barium chloride or bismuth nitrate. Not only plain glass, but also colored glass may be subjected to this process.

Art glass for cathedral windows may be glass "colored in the pot," or it may present a marbled or variegated appearance, due to imperfect mixture of two lots of glass, differing in color. Its surface may be smooth, or it may have been subjected while hot to the "roller treatment," and given the "hammered," "rippled," or "moss" surface, so generally admired in art glass.

Art glass, like any other plate glass, may be softened by skillful heating, and may be bent and molded over forms, to any shape desired.

Artificial pearls are made from tubing. The beads are coated on the inside with a mixture of finely ground fish scales and ammonium chloride. But for very cheap beads a paraffin-like substance is used for the coating.
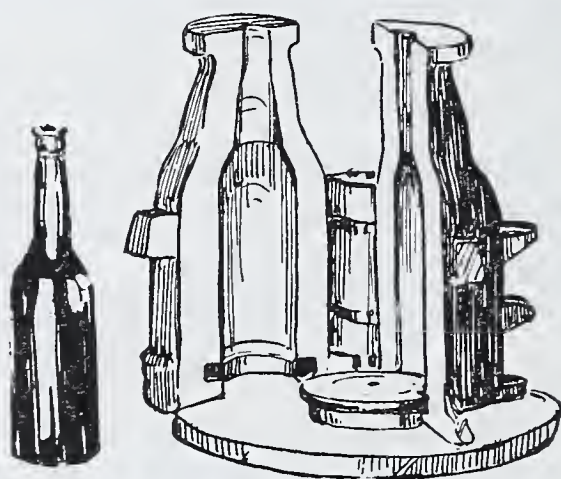
Mould for Automatic Bottle Machine

Bottles and Other Containers

Common bottles are made of soda-lime glass. If special care has been taken to obtain a clear and practically colorless glass of considerable brilliancy, the bottles are, in the channels of trade, classified as "flint" ware, although real flint glass is quite different in composition, being a potash-lead glass. True flint glass is not used for bottles.

Bottles are made by blowing the glass-bubble in a mold. This was accomplished by lung power until rather recently. At the present time common bottles are generally made by means of automatic ma-

chines, which operate by sucking the required quantity of semi-liquid glass into a mold, and then, by air pressure, ballooning the mass to fit the enclosure.

Homœopathic vials are not made in a mold, but from tubing, cut to the required length. Automatic machines fuse shut one end, and shape the other to a cork or screw-mouthed top. Automatic carriers convey the tubes to the slender blow pipe flames by means of which the ends of the tubes are re-heated for the sealing or the shaping.

Shallow dishes, or jars, are made by pressing the glass into the mold by means of a plunger.

Museum jars are blown and shaped by hand. The operation involves blowing a balloon, lengthening this by swinging, flattening the apex, making the balloon cylindrical by rolling it on a plate, cracking the cylinder off the blow pipe by means of a thread of hot glass, spinning a layer of glass around the top, and with a tool, shaping a serviceable lip.

Blowing Hollow Ware

Hollow chemical glass ware, such as flasks and beakers, is always blown by lung power, shaped by swinging, twirling, etc., and its production calls for exceptional skill.

Condensers, Soxhlet tubes, potash bulbs, and similar glass apparatus familiar to chemists, can be constructed from tubing, which is heated in a blast or blow pipe flame, so that it may be blown into bulbs, constricted, "bent," or welded, as may be required. To weld glass in the making of apparatus, it is sometimes found necessary to use a low-melting glass as a kind of solder. Glass blowing and shaping with the aid of a blow pipe flame is usually spoken of as lamp work—in contra-distinction to the work at the glass furnace.
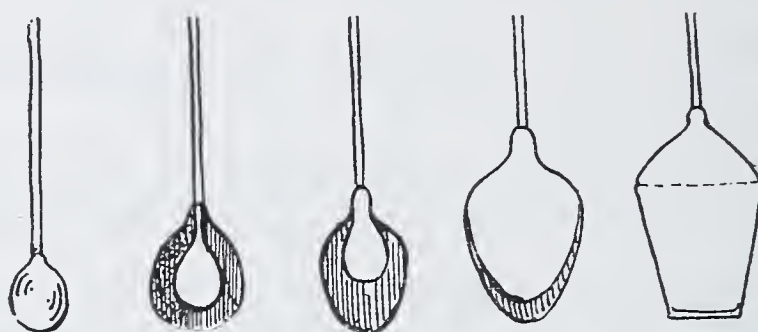
A. The Gather of Glass. B. The Distention by Blowing. C. Showing Result of Swinging. D. Further Distention and More Swinging. E. Flattening Apex, Rolling Sides to Desired Taper and "Cracking Off."—After Thorpe's Dictionary of Applied Chemistry.

Glass Tubing

A large mass of glass is gathered on a blow pipe, and by blowing, swinging and rotating on a plate or marver, is formed into a thick-walled cylinder. A helper gathers a small mass of hot glass on an iron rod, and attaches this to the apex of the aforementioned cylinder. The latter is now supported between the two operators, and is drawn out as the helper walks backward, and while the chief operator rotates his blow pipe, and blows, so that the tube cannot collapse. Experienced tube blowers will in this manner make tubing seventy-five to eighty feet in length, of the desired diameter and of practically uniform bore.

Tubing is made more rapidly by an automatic machine, which delivers about two feet per second. By compressed air, the molten glass is made to assume the form of a cone which issues from the opening as a tube, and a mechanical carrier pulls the tube forward at a steady rate to the cutting machine, by means of which definite lengths are cut and stacked.

Cutting Glass

In the factory a large cylinder of glass may be cut by spinning a thread of hot glass around it. A wire, electrically heated, accom-

pishes the same result. Funnels, bottles and other thick-walled ves-
sels may be cut by the use of a blow pipe flame, which is made to is-
sue through a narrow slit, before which the vessel is rotated. There
are also "glass saws," with small teeth, diamond-tipped, which eat
their way through hard glass with astonishing ease.

Annealing Glass Ware

When a drop of molten glass is allowed to fall into water, the
glass blob solidifies, forming the well-known Prince Rupert drop,
which, when its surface is scratched, or its tail broken off, flies into
countless fragments. Whenever red-hot glass is cooled too quickly,
it exhibits internal strain, more or less pronounced, and breaks on the
slightest provocation, or for no apparent reasons—so it seems. In
short, it exhibits, though in a lesser degree, the characteristics of
the Prince Rupert drop. But when the cooling of the glass is very
gradual, the necessary internal readjustments take place, internal
strain is not developed, and the glass possesses much greater
strength and endurance. We say it has been annealed.

Strains in glass ware present no visible evidence of their pres-
ence, but they may readily be detected by means of the polariscope.

The annealing operation may vary in point of time consumed,
from four or five hours to several days, and is determined by the
composition of the glass, and the nature of the ware subjected to
the process. The range of temperature is likewise indicated by the
chemical composition; thus soda-lime glass annealing at a lower
temperature than does resistive glass, and glass with a high silicon
content at a higher temperature than glass with a high soda content.
Researches of great importance have been carried out in the last few
years on the problems incident to annealing, and the results obtained
have made possible a considerable shortening of the operation. One
may see also in a modern plant, small and large articles, thin-walled
and thick-walled ware, being annealed at the same time—a procedure
which was not deemed practicable a few years ago.

There are two distinct types of annealing ovens. In the one,
called the annealing kiln, the fire is allowed to die down gradually;
in the other, called a *lehr,* the glass ware rests on a moving platform,
and, at a certain (very slow) speed, passes through the oven, which
is virtually a huge muffle furnace, terminating in a kind of tunnel
about forty feet long, but which, for certain types of glass ware,
may be extended to the length of three hundred feet.

Chemical apparatus made by bending, ballooning, constricting and uniting tubing, requires re-annealing, as this so-called lamp work involves heating the glass to redness and to its softening point. Such apparatus, constructed in a chemical laboratory, may accordingly be expected to be exceedingly frail, and subject to fracture— a fact which every chemistry student has no doubt observed. It will be seen also why a fracture in thick-walled ware cannot be mended successfully by welding—certainly not if the welding is to be done in the proximity of a liquid.

Optical Glass

The manufacture of optical glass is now successfully carried on in this country. As has been said, such glass may be lead glass, or barium glass, may be silicate, boro-silicate, or phosphate; in short it exhibits a considerable range in its composition. In the making of optical glass the use of decolorizers is precluded; so pure materials, particularly iron-free sand, must be employed, for manganese, and other decolorizers, which remain in the glass, exhibit absorptive action on light waves, thus rendering the glass unfit for certain purposes.

Optical glass must have the proper refractive indices for the different wave lengths of light, must be free from color, and from defects, such as waves, opaque spots, bubbles, etc.; must be free from strains; must not scratch or break easily, yet must be hard enough to admit of grinding and polishing. It should also show high resistance to weathering, and not lose its brilliancy with age.

The importance of the optical glass industry is apparent when we remember that not only telescope lenses, but also microscope and camera, as well as spectacle lenses, are of optical glass. Without it, many of us would go through life with myopic or distorted vision. There would be neither photographs nor moving picture shows. Bacteria would be with us, to be sure; but their connection with human ills would be unknown, and many of the benefits which have resulted from scientific progress, would not be ours to enjoy. Indeed, it is impossible to enumerate here the divers lines of scientific research made possible by the lens maker, and to estimate the debt which humanity owes to the optical glass industry.

It has been possible to touch only the high spots in this story of glass—the substance which was first used for beads and ornaments, then for small containers and vases, next for table ware and for windows—and now—well, for how many purposes *do* we use glass? We huddle behind our plate glass window, as snug as a worm in a hazel-nut, yet may look out upon life, through our bifocal spectacles, and see the milkman deliver his supply in glass bottles. When darkness falls, we turn on the Mazda light—a glowing filament of tungsten, suspended in a bulb of glass, and receiving its extraordinary powers through a wire run along poles, but affixed to the same by the intervention of gobs of glass. We sit down at dinner to a table resplendent with glass, and conclude our repast with a quarter section of a pie baked in a pyrex dish. Then we may glance through the family album, and question whether it is really true that the photographic lens never lies. Having consulted a plate of glass backed with a film of silver, to "see ourselves as ithers see us," we may go to the movies, and view the high-priced footprints left by Charlie Chaplin on the sands of time, as recorded through the lens of the camera man, and projected also by a lens of glass. When the supply of diamonds, rubies and emeralds is not equal to the demand, we eke out with potash-lead glass, which has been made to serve as a setting for many an engagement ring. Through glass we search for the elusive microbe, for the spectrum bands of the rare element, for the distant stars. Our great industries present but amplifications of work carried out first in test tubes or flasks.

The splendid advances in chemistry and in biology, made in recent times, would not have been possible but for glass. Truly, 'tis an interesting subject, with many ramifications, and well worthy of our interest and further study.

BACTERIAL PREPARATIONS IN COMMON USE.

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Pharmacy and Science.

The layman generally thinks of bacteria as injurious and unde-
sirable invaders. Such opinion and thought have been common, be-
cause the average individual is more apt to regard only bacteria that
cause disease and diseased conditions. It is not a frequent occurrence
for the layman to hear of or come in contact with the useful micro-
organisms. There are, however, many products which are really bac-
teria and extensively used by everyone but not generally regarded or
thought of as being bacteria.

This evening there will be no attempt made to discuss the
bacteria that are of value in industries, and in the production of
desirable products. Neither will there be considered the many bac-
teria that produce disease. I will venture to ask your attention to
a consideration:

First, of living bacteria sold and used as such in the treatment
of diseased conditions.

Second, of dead bacteria or of attenuated bacteria (*i. e.*, bacteria
that have been so treated that they have lost their power of produc-
ing disease), that are used in the prevention, to assist in the diag-
nosis, and in the treatment of diseases, which they in their original
living condition cause.

Third, of preparations made with bacteria as a starting
point, which are subsequently used to prevent, to assist in the diag-
nosis, and to treat diseased conditions caused by these same bacteria,
when in a living and actively growing condition.

May I, at this time, impress upon you the fact that it is not ad-
visable for the layman to attempt to use these preparations without
the advice of an attending physician or other competent authority. It
is due to the misuse and abuse of preparations of this kind that indi-
viduals pass unwarranted judgments concerning them. This holds
true even for the simple yeast preparations. Some of the latter
have been extensively advertised and exploited with false claims.
Even the simple yeast cake is contraindicated in certain conditions
and in others should be employed judiciously either with or without

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other medications, as the practitioner may see fit depending upon the existing findings.

There are many individuals who refuse medication or treatment with some of the preparations which will be discussed. This is due to the prejudiced ideas that belong in days gone by. If I can possibly succeed in changing such thoughts or if by informing you of the methods of preparation, the mode of application or administration and the function of these products, you will co-operate in the future with the medical profession, I will think my time here this evening well spent.

Of the first class I mention the following three micro-organisms which the layman occasionally hears of: Yeast, Bulgarian Bacillus, and Bacillus Acidophilus. These are sold and used in their living condition.

To the scientist, the term Yeast includes a large group of oval or round bacteria about one-four-thousandth of an inch in diameter and which multiply by a process known as budding. Each yeast cell, about twenty minutes after its existence, develops a slight projection or bud. The latter grows until it is nearly as large as the original cell. When ten to fifteen such buds are formed, they separate. These buds, now independent cells, live a separate existence and repeat the process of reproduction, if conditions are still favorable for their growth and development.

In this yeast group there are specific members, some of which are disease producing and others of value in industries. Many of the members are non-disease producing, while some are not desired in the industries, as they interfere with the production of specific end substances.

The layman uses the term yeast as a commercial term. The latter is applied to a specific member (the saccharomyces cerevisiæ), which is manufactured and sold in bulk. Such packages consist of millions and millions of these cells of the specific member (as mentioned) pressed together in a solid mass.

Pasteur was the first to describe and give the characteristics of the yeast group. He observed them while investigating the various phases of fermentation. The study of this group was taken up by other investigators. Today considerable data is available concerning the important part the commercial yeast plays in the production of alcoholic drinks. We are told it is the little things in life that

count. You are well aware the trouble that these little yeast cells are causing in the proper enforcement of the Eighteenth Amendment to our Constitution. Home-made alcoholic drinks, palatable, but more frequently non-palatable, are always possible with yeast around.

You are all familiar with the part this same commercial product plays as a leavening agent in bread. Yeast was employed as a curative agent by Hippocrates, and from his days to the present time articles on the therapeutic value of yeast have appeared. The most careful and most thorough studies on the curative value of yeast have been done within the last five years by many well known investigators and clinicians. It is the opinion of some of these men that yeast, because of its vitamine content, is an efficient food and if controlled properly will be found to assist in the increase of appetite which will in turn mean more utilization of other nourishing foods.

It was also found that yeast, as a food, aids in bringing about a natural uniform elimination of waste. Besides this natural laxative effect, it will in some cases check putrefaction in the intestines. This it does due to the fact that the substances produced when yeast causes fermentation are such as to stop the further growth and development of the organisms that are present causing the putrefaction.

Yeast, acting as a food, aiding digestion, assisting to create an appetite and properly eliminating the waste materials, is therefore of value as an aid in the treatment of some diseases in which an increase of resistance is desired. It is with this thought in mind that yeast is used as an aid in the treatment of boils, carbuncles, acne, and other conditions where pus is produced. The market has been flooded with all kinds of yeast tablets and yeast preparations, but most practitioners have found that it is best and cheaper to use fresh yeast. The form supplied as the yeast cake, with which you are all familiar, is to be preferred. Dried yeast preparations have been found to possess a diminished activity as compared with the fresh cakes. The yeast can be used in conjunction with any other medicinal agents that the attending physician may advise.

The other two organisms are used mainly for the property they have of decomposing lactose (milk sugar), with the production of lactic acid.

The large bowel is one of the richest cultural environments for

the growth of bacteria. There is constantly present abundant quantities of organisms, some harmful and some beneficial. In many individuals the putrefactive germs tend to predominate. When this condition takes place there is produced by these organisms various substances which, when absorbed and carried through the blood stream, act as poisons and produce the condition commonly known as auto-intoxication. The symptoms of the latter are manifested in many ways, and unless properly treated may lead to the development of more serious ailments.

The intimate relationship between putrefactive changes in the alimentary canal and the disturbances of the important organs and in turn of the health in general is commonly recognized. The use of purgatives and chemical germicides or so-called intestinal antiseptics have proved ineffectual for getting rid of the bacteria that cause the production of the toxic substances. As Metchnikoff pointed out in his remarkable contribution to science in 1904: "Enough germs remained in the intestines to furnish abundant new cultures. The elimination of all new foods stopped new contaminations, but it was necessary to find some way to suppress the bacterial flora already existing from exercising harmful actions." Experimentation has revealed the fact that all the bacteria that produce lactic acid generally have the power of arresting the growth of bacteria which produce putrefaction. Metchinkoff recommended the use of the Bulgarian Bacillus to obtain the proper lactic acid content.

This organism, though having the power of producing large quantities of lactic acid, is in itself non-injurious to the human body. Experiments have revealed that the best procedure to adopt is to produce this inhibiting chemical (that is, the lactic acid), in the immediate environment of the putrefactive organisms that are to be destroyed: thus the use of the harmless micro-organisms in preference to the free acid itself.

The Bulgarian Bacillus mixed with starch or sugar of milk in tablet form, or, better still, Bulgarian Bacilli in a liquid culture medium, are employed. It is advisable that fresh cultures are used and these are to be preferred to the tablets. The fresher the cultures the more can one be assured of the efficiency which will be produced. The Bulgarian Bacillus produces exceedingly large amounts of lactic acid. The organisms survive and continue to

live in the intestines for a long time after administration. It is claimed that they multiply rapidly in the intestines while producing these exceedingly large quantities of lactic acid. The latter hinders the growth of the harmful bacteria commonly found as the cause of intestinal fermentation and putrefaction.

The tablets can be employed but it is very important to be assured that they are fresh and are in turn kept at a cold temperature, as in an ice box, and renewed as per date on container. The same warning holds true for the liquid cultures, but generally the latter keep better than the tablets.

The Acidophilus Bacillus is an organism which is closely related to the Bulgarian Bacillus and has in recent years come into prominence.

This organism is one of the few acid-producing germs that appear to be a normal inhabitant of the intestinal tract of healthy infants. Experimentations have revealed that the bacterial content of the large intestines can be completely changed by feeding Bacillus Acidophilus. The latter becomes implanted in the large intestines, and because this organ is a suitable habitant, the organisms thus introduced flourish, multiply, and replace putrefactive and other injurious bacteria. The Acidophilus Bacillus itself is harmless, and during its development there are no poisonous by-products produced.

The Acidophilus Bacillus is sold either in tablet form or in liquid cultures as in the case of the Bulgarian Bacillus. In certain quarters there seems to be a demand created for Bulgarian and Acidophilus Bacilli. There are some manufacturers who have marketed the so-called B. A. tablets to meet this demand. The latter are tablets containing large quantities of the Bulgarian and Acidophilus Bacilli.

There are some investigators who have not only advised the administration of these lactic acid producing bacilli by mouth but also by enema.

In the second and third groups I include the many vaccines, therapeutic sera and antitoxins.

A vaccine, as the term is used today, is an infective agent so treated and modified as to prevent its power of multiplying and growing in the body. It is not, however, changed as to affect or prevent the production of specific protective substances when injected into the body.

The term vaccine has been misused and abused, not only by the layman but by some scientific and professional men as well. The former have, in some instances, misused this term in almost the same way that the term "drug" has been misused. The scientist refers to any remedial agent as a drug. This may or may not be habit-forming. Then why speak of drug "addicts"? Why not be specific and say "habit-forming drug addicts," "narcotic drug addicts," or, as advised and practiced by some people, the use of the slang term, "Dope," and say "dope addicts"? Why should one misuse or abuse useful terms? In like manner the term vaccine has been applied erroneously to many products.

The term itself is derived from Vaccinia (from the Latin word meaning cows). Dr. Jenner first attempted to create a resistance against smallpox, by using the material from cows diseased with cowpox. The method of inoculation was later termed vaccination, and the material employed was called vaccine. Unfortunately the agent causing smallpox is still unknown. Though it is possible to prepare so-called smallpox vaccine, an effective remedy to be used to prevent smallpox, nevertheless the composition of this product is unknown. It may be said to be a modified unknown infective agent. The infective agent itself being poisonous is at times called a virus, then why not call the so-called smallpox vaccine, modified smallpox virus or as long as it is used to produce antibodies or specified protective substances, against smallpox, let it be termed anti-smallpox virus? In like manner, any modified unknown infective agent can be termed a modified virus, or anti-virus. Such terms would be descriptive of the products. The only other important preparation that falls in this class is so-called Rabies Vaccine, used to create a resistance against Hydrophobia. This can be properly termed Modified Rabies Virus or Anti-Rabies Virus, since the causative agent of Rabies or Hydrophobia is unknown.

There are certain preparations made by extracting the protein or albuminous matter from the pollen of various plants and grains. These are used as aids in the treatment of Hay Fever. For many years they were known as Hay Fever Vaccines. The proteins in the pollens are not necessarily the sole cause of Hay Fever, then why say Hay Fever Vaccine? Why not use the term actually descriptive of the product, Hay Fever Extract, or, better still, Pollen Extracts?

The term Vaccine is in most instances applied to what should be specifically termed "Bacterial Vaccines." A coined name, "Bacterin," has been applied to this class of products and in many ways is to be preferred.

A Bacterial Vaccine or a Bacterin is a suspension of dead or modified bacteria or products from the latter in a very weak salt solution to which there is generally added a preservative. The proper use of vaccines in the prevention of certain diseases is one of the most notable of triumphs of modern medicine. It was the same Pasteur who revolutionized medicine by the introduction of the germ theory of disease who subsequently cleared the way for the investigation of the underlying causes of immunity and the introduction of the use of vaccines. In 1879, while working with the organisms which produce chicken cholera, he accidentally found how to modify these disease-producing germs so as to use them later in chickens, to create a resistance against this dreaded disease in fowls—Cholera. Pasteur found that germs possessing a high disease-inciting power became weakened as these organisms increased in age. When the latter, having lost their disease-inciting power, were injected, it was found that the fowl received the same disease but not in the fatal form, with the result that after recovery, the animal was able to withstand the attack of highly disease-inciting strains of the same organism.

Pasteur's original method had to be somewhat modified, inasmuch as it was more or less difficult to be always assured that the bacteria had been sufficiently weakened and that no living organism, especially in appreciable numbers, remained. Should a few living ones that possess a high disease-inciting power still survive, there is always a possibility of setting up a fatal disease, rather than a mild form to protect. Experiments soon revealed that dead bacteria and still better bacteria, which were so altered as to have lost their disease-inciting power, had the same power of causing one's system to produce protecting substances. It was found that such physiological alteration can be produced by low heat or by the application of a mild germicide.

Bacterial vaccines or Bacterins may be divided first into two distinct groups: autogenous and stock. The former are prepared from material obtained from the lesion or from the infected part of the individual into whom later the preparation is to be injected. Stock vaccines are those prepared from stock cultures kept in the

laboratory. A simple Bacterial Vaccine is one made from only a single species of micro-organism. Mixed Bacterial Vaccines are those containing two or more different species of bacteria.

The first step in preparing vaccines is to obtain a culture medium most suitable for the growth of the organism or organisms from which the vaccine is to be prepared. A solid medium is generally employed, plain agar culture medium being satisfactory in many instances. The latter is a product prepared by adding agar, a weed, to beef broth, which is a preparation made from meat and containing some inorganic and nitrogenous matter, the end product afterwards being sterilized. The agar, after being dissolved in the weak beef infusion, will cause the entire mixture to solidify upon cooling, thus giving a solid culture medium. This can be liquified if placed in a boiling water bath, but will solidify again when ordinary room temperature is reached. In culturing some organisms, it becomes necessary to fortify the plain agar medium with a natural fluid. For this purpose, blood, blood serum, and similar natural fluids are employed.

The culture of bacteria is then placed in an incubator at body temperature for twenty-four hours. At the end of this time the bacteria are procured by pouring a weak salt solution over the culture and gently shaking until all the micro-organisms have been suspended. The salt solution suspension of bacteria is then poured into a sterile container and shaken by some mechanical device or by hand so as to break up the clumps and make a uniform emulsion.

Bacterins are standardized by estimating the number of bacteria in the suspension. There are three methods commonly employed for estimating this number. The one worth mentioning at this time is the so-called Wright's Method. A small drop of the suspension of bacteria is mixed with an identical drop of blood. This is prepared for microscopic examination. We then can obtain a comparative ratio as to the number of bacteria and red blood cells present by actually counting the numbers of both. It is logical to assume that this proportion will be approximately the same in larger quantities as is found when a drop of each is compared. Knowing the approximate red blood cell content of a normal individual, by comparative proportion we can thus compute the amount of bacteria present in the suspension, after once establishing the ratio between the two. After the number of bacteria has been determined, the

suspension is then diluted with a sterile weak salt solution so as to bring the content to any desired number per drop or per any given volume. The suspension is then sterilized by heat in a water bath at a minimum temperature and time of exposure that will kill the bacteria. This in most instances is 60° C. for one-half hour. A small quantity of a preservative is then added.

The Bacterial Vaccines are then subjected to purity and safety tests and placed in sterile containers. The greatest value of vaccines has been their application in the prevention of diseased conditions. Their use, generally in from three to twelve or more injections, given at intervals of at least a few days, and administered generally subcutaneously (that is, beneath the layers of the skin), is for the purpose of creating protective substances. By the presence of the latter the individual is in the position to counteract the effects of living organisms of the same type should they invade the system within a few months to a year after the period of vaccination.

If vaccination against Typhoid had not been carried out in the Great World War and had the same rate of infection prevailed as in the Spanish-American War, we should have had to each million men in the army the appalling number of 192,056 cases and 14,633 deaths from Typhoid Fever. It is hard to completely eradicate Typhoid Fever by sanitary methods alone, even though water, milk and foodstuffs as well as other sanitary measures are closely guarded. It is almost impossible to detect all Typhoid carriers as we do not always know of their existence. It is therefore apparent that Typhoid vaccination added to sanitary control would, if universally applied, go far towards making Typhoid Fever as uncommon as Smallpox. Many physicians in certain circles and sanitarians in general are attempting to popularize Typhoid vaccination. The advantages that would accrue warrant such a movement. You may at times hear of the so-called triple vaccine. This contains the Bacillus Typhosus, Bacillus Para Typhosus A and Bacillus Para Typhosus B. This so-called triple vaccine causes immunity not only against Typhoid Fever but also against Para Typhoid Fever, which, though uncommon in this area, is apt to be observed at frequent intervals in the southerly states and in certain sections of Europe.

Vaccines have also proven of value in the prevention of Asiatic Cholera and Bubonic Plague. They are being experimentally used

with the hope of proving effective for the prevention of Pneumonia, Influenza, Meningitis, Whooping Cough, etc.

Vaccines have also been used for their curative value. For this purpose they have been extensively employed, especially in chronic diseased conditions, in which pus or some discharge is present, as in boils, pimples, carbuncles, chronic running ears and chronic running sores in other parts of the body and in chronic nose and throat trouble, etc. In many of the latter cases marked success has been reported when these products have been employed judiciously. Many clinicians have recently been using vaccines even in acute conditions with varying degrees of success.

The Anti-Bacterial, Anti-Microbic or Therapeutic Sera are the sera (or the liquid portions) of the blood of animals in which there has been created a resistance against specific bacteria, the prepared sera in turn containing protective substances which are capable of counteracting the effects of these same organisms when living and active. In the preparation of these products, any animal can be employed. Horses are, however, commonly chosen for sera production inasmuch as they can be kept cleaner. They stand the injections and treatment better than other animals. Horse serum itself is less harmful than the sera of other animals. The cost of production is cheaper and from a commercial standpoint the yield of active serum is greater than would be produced in other animals.

The horses that are selected must be absolutely free from disease. They are given a thorough examination by a veterinary surgeon and kept under close observation for at least two weeks. During this time tests are made to insure freedom from glanders and tuberculosis. Some frequently practice the administration of a prophylactic dose of tetanus antitoxin, so as to create a temporary resistance against tetanus or lockjaw. No animal is retained unless found to be physically perfect. During the entire period that the horse is employed for the production of the sera, care is taken to be assured that they are constantly healthy and vigorous.

May I now explain briefly the manufacture of anti-Pneumococci sera used to counteract the effects of Pneumococci, which are the causative agents of most cases of Lobar Pneumonia. Just as the Anti-Pneumococci Sera are prepared, so are all other anti-bacterial sera prepared, with but very little variation.

Pneumococci are obtained from as many different sources as

possible, in other words, the cultures that are used are ones which have been prepared from many different strains of the bacterium. The different individual strains are grown on cultures, and afterwards mixed together. These are then sterilized in a water bath at 60° C. for one-half hour. In other words, we practically start with a vaccine. The horses are usually infected with these dead or modified cultures for a period of from two to four months with increasing doses after each injection, depending upon how the animal reacts. The injections are made under aseptic conditions subcutaneously (beneath the layers of the skin). The number of injections consist of from one to three per week. The intervals between injections vary, depending upon the susceptibility of these horses and the length of time necessary for the complete subsidence of the various symptoms which develop, i. e., elevation of temperature, rigor, dejection (altogether commonly known as the reaction). At the end of the two to four month period, very small doses of the mixed strains of the same bacteriuu, that are alive and active, are given. Increasing doses at stated intervals are employed. At about the end of from six to eight months after the first injection was started, the animal is ready to be bled. So as to counteract the effects of the organisms, the horse develops in his system specific protective substances, generally termed antibodies. The production of the latter is in quantities and in excess of the needs at the time of the injection of the organisms. These antibodies or protective substances remain stored away for a period of time, and are ready to exert their influence against the organism for which they are specific. To bring out clearly what is meant when we say these protective substances or these antibodies are specific, may I say that Anti-Pneumococci Sera will only be efficient in counteracting the effects of Pneumococci and no other organism. Anti-anthrax sera will only be efficient in counteracting the effects in anthrax infections and have no effect in infections caused by other bacteria.

After a preliminary test, if the blood of the animal is found containing a high content of protective substance, the horse is ready to be bled. The animal is led into a specially constructed stall where the operation of bleeding is under perfect control. These stalls are in buildings of solid concrete and are separated from the stables and other buildings. The ceilings, walls, floors, and all compartments are constantly kept thoroughly aseptic. Appa-

ratus, instruments and all equipment that are used here are thoroughly sterilized.

The animals are now washed with soap and water, their necks are shaved and asepsis is maintained by washing with an antiseptic solution and covering their entire body except the head and jugular vein with a sterile sheet or apron. A sterile cannula (a large needle), to one end of which is attached a sterile rubber tube, is inserted into the jugular vein. The latter is at times made prominent by various means of compression or the skin surrounding the vein may be incised. The blood is allowed to flow through the rubber tube into high sterile glass cylinders which are protected by parchment covers. Anywhere from one to two gallons of blood can be obtained at one time without injuring the horse. In some instances, if the blood serum of the animal is found to still contain a high protective substance content, additional bleedings are repeated. If the antibody content is diminished, these horses can then be reinjected as previously described, so as to yield a high content of these specific protective substances.

The cylinders, containing the blood, are placed in refrigerators and the blood allowed to clot. After the clotting, the serum is collected in sterile containers in which there is placed some preservative. The sera are then filtered (if possible) through special filters to rid them of bacteria which may have accidentally gained entrance. They are then tested for sterility and toxic substances, and, if found satisfactory, they are placed in sterile containers as the anti-bacterial sera.

The composition of the complex bodies which are present as the valuable protective substances (acting as specific antibodies or therapeutic agents against the bacteria which produce them), is not known. On this account it has been almost impossible to isolate them or to remove the excess quantity of valueless and, in some instances, harmful blood serum. The methods of testing or actually determining their efficiency are numerous and vary in the different anti-bacterial sera. Unfortunately there is a lack of standardization, which we hope will be overcome in the near future.

The anti-bacterial sera are employed in the treatment of acute diseased conditions in which the causative agent has invaded all parts of our system. It is employed at a time when there is desired an immediate introduction of protective substances to counteract the effect of the invading organisms. The individual himself is

either unable or time does not permit to wait for the production of these antibodies in his system, because of the seriousness of the condition. Therefore they are introduced after obtaining them from outside sources, in this case, the horse.

They are generally administered subcutaneously under the skin of the abdomen or between the scapulae. Injections into the vein' are employed in desperate or in the late stages of acute diseases. The only exception to this rule is in the use of anti-meningococcus serum. This is employed to counteract the effects of the meningococcus, the causative agent of epidemic Cerebro-Spinal Meningitis. This is administered directly into the spinal canal, removing first an amount of spinal fluid equivalent to the quantity of serum that is to be injected.

The following are the more important anti-bacterial sera that have been found beneficial, if employed as early as possible, and freely after the infection has been diagnosed: Anti-Anthrax Serum, used in the treatment of Anthrax in humans; Anti-Dysenteric Serum, found of value in reducing the mortality rate of bacillary dysentery; and Anti-Meningococcus Serum. The latter is probably the most successful of the different anti-bacterial sera. Anti-Pneumococcus Serum is of value as mentioned before.

Anti-Streptococcus Serum is used in infections throughout the entire system caused by the streptococcus. Versins Serum (anti-plague Serum), made from the bacillus pestis, the causative agent of plague, is most frequently employed as a preventative against plague. It is also of value in the treatment of this disease if used early.

All bacteria produce a poisonous principle, which is scientifically known as Toxin. In mose cases this toxin is held within the cell wall of the bacterium proper, to be liberated when the cell wall of the latter is broken up. A few of the disease-producing organisms, however, produce a toxin which is immediately thrown forth from the cell. This is known as an ecto, exo, or extra-cellular toxin. The diphtheria and tetanus bacilli, the causative agents of Diphtheria and Lockjaw respectively, are two of the commonly observed disease-producing organisms that produce extra-cellular toxins. It is due to the presence of the latter throughout the system rather than to the bacteria themselves that the symptoms common to Diphtheria and Tetanus or Lockjaw are produced. It is mainly to overcome and inactivate these extra-cellular toxins that the class of biological products known as antitoxins are employed.

The antitoxins are the true antitoxic bodies obtained from the serum of the blood of animals which have been immunized against specific known extra-cellular toxins. These antitoxic bodies are obtained from the serum, dissolved in a weak salt solution, filtered, and a preservative is added. After standardizing them, tests are performed to insure their purity. They are then placed in sterile syringes or containers ready for use.

In the preparation of antitoxin, horses are employed. All precautions as observed when these animals are used for the production of anti-bacterial sera are taken here. Instead of injecting the horses with bacteria, the injections are made with the extra-cellular or the true soluble toxins of the bacteria. I call your attention specifically to the production of Diphtheria antitoxin. Tetanus and other antitoxins are manufactured in like manner with little variations.

A culture of the Diphtheria bacillus is selected which is found by observation to produce a large amount of a powerful extra-cellular or soluble toxin. The organism is usually obtained originally from patients suffering from Diphtheria. The latter is cultivated on suitable solid culture media and when kept on hand is known as the "Mother Culture." When needed for the preparation of antitoxin, some of the organisms from the latter are replanted on an additional media and kept in an incubator at body temperature for twenty-four hours. These known as "seed cultures" are therefore employed for the planting of the organism into sterile flasks containing large quantities of sterile veal broth. The latter are placed in compartments or incubators kept at body temperature, for a period of from six to eight days. Within this time, the Diphtheria bacillus is constantly multiplying, giving off large quantities of extra-cellular toxin, which, being soluble, goes into solution. The cultures are then usually examined, and, if found pure or free from contamination, an antiseptic is added and the mixture is also allowed to stand for twenty-four hours. The bacteria are killed by this procedure. They are then filtered out and the clear filtrate containing the soluble toxin is stored away protected from the action of heat and light, until required for use.

Having obtained fit horses and having determined by tests the fact that the toxin is active, the development of the antitoxin can then be started. Due to the susceptibility noted in various horses, the first doses of soluble toxin which are administered are very small or

otherwise reduced in strength by slightly heating, adding an antiseptic, or combining it with antitoxin and gradually withdrawing the latter, as the injections are continued until pure toxin only is injected.

The injections are made under aseptic conditions beneath the skin in the flank region. From one to three injections are given every week, each injection consisting of gradually increased doses. The intervals between injections depend upon the susceptibility of the horses or the subsidence of any reaction that may develop.

So as to counteract the effects of toxin, the horse develops in his system specific substances which will counteract or neutralize this toxin. These protective substances being specific for toxin are called antitoxin or antitoxic bodies. The antitoxin content of the blood increases with increased doses of toxin, until such a point or level which is reached by each animal when the antitoxin contents remain stationary and are not followed by further increase, even though the injections with toxin are continued. This level is determined in each animal by obtaining a small quantity of blood from time to time, beginning usually from six to eight weeks after the first injection.

The strength of antitoxin and the length of time required to produce a maximum yield of the latter will vary greatly in each animal due to susceptibility. At times it happens that some horses which have been treated with injections for long periods of time will yield a serum of so low an antitoxin content, as not to warrant the use of such animal, as the resultant product is only of little commercial value.

At the end of the period when a maximum yield is produced, which on an average is from three to four months after the first injection, the horse is bled. The bleeding is conducted in an almost identical manner as explained previously in the manufacture of antibacterial sera.

The blood is allowed to pass into large vessels containing chemical solutions which prevent the blood from clotting. The liquid portion is then treated by various procedures in which the true antitoxic bodies are finally obtained. These are purified, dissolved in a weak salt solution, filtered and standardized. A preservative is added and they are then placed in suitable containers ready to be used.

Diphtheria antitoxin is used both as a remedial and a prophy-lactic agent. It has been found a specific in the treatment of Diphtheria. It is usually administered hypodermically or intra-muscularly. In advanced cases, when immediate relief is required, it is given intravenously. Administration during the early stages of the disease, when the symptoms just appear, is always to be prac-ticed, as the more time that elapses before the antitoxin is injected, the less chance will there be for a prompt or hasty recovery. Large doses are generally administered so as to be assured of an antitoxin in excess of the poisonous toxin. An excess of the former will never produce harmful results.

Diphtheria antitoxin is a valuable prophylactic agent. It should be administered to all who have been exposed to infection with Diphtheria. It should, however, be stated here that this protection lasts for not more than two to three weeks. Within recent date mixtures of Diphtheria toxin and antitoxin have been marketed and used as a more valuable prophylactic agent than Diphtheria anti-toxin alone. Generally three doses are given, the later doses con-taining more of the toxin and less of the antitoxin. This treatment is being employed successfully to create a more lasting protection against Diphtheria in children or in adults, who are more apt to be found in an environment where Diphtheria is common.

The Tetanus bacillus is widely distributed in nature. The chances of Tetanus or Lockjaw setting in are numerous, especially when an injury has caused deep, lacerated wounds in which consid-erable tissue destruction was produced, and in which foreign par-ticles have become imbedded.

Under all such conditions, it is imperative that tetanus antitoxin should be administered so that the antitoxin may neutralize any toxin that may begin to form. If the toxin is allowed to develop, it quickly invades the motor nerve cells, forming a combination or union which the antitoxin cannot break up. The greatest value, therefore, of tetanus antitoxin is as a prophylactic agent. Tetanus antitoxin administered immediately after infection or after early symptoms set in will quickly neutralize the soluble toxin before it reaches the motor nerve cells, thus preventing a strong union.

Other antitoxins have been prepared from the soluble toxins from other organisms. The latter have thus far been found to pos-sess but slight curative values.

Another class of preparations which you may hear of is the so-called "Sensitized Bacterial Vaccines" or "Sero-Bacterins." The latter are prepared in the same manner as the bacterial vaccines or bacterins, but differ in the following additional steps:

After the bacterial suspension has been thoroughly emulsified and the number of bacteria determined, a portion of the serum of an animal (that had been immunized against the same species of bacteria as found in the suspension), is added. The mixture is allowed to stand for twenty-four hours in an incubator at body temperature, with occasional agitation. At the end of this time, the mixture is centrifugalized and the supernatant liquid (consisting of the weak salt solution and serum), is discarded. The remaining bacteria are then washed and again suspended in a weak salt solution. After a preservative is added, the preparation is treated in like manner as are the plain bacterial vaccines or bacterins.

The treatment with anti-bacterial sera is said to sensitize the bacteria so that they are more easily attacked by the forces in the patient's system.

The sero-bacterins are found to be more rapid in their production of protective substances. They usually minimize undesirable reactions. Larger doses of sensitized bacterial vaccines at more frequent intervals can thus be given.

Sensitized Bacterial Vaccines of practically most of the bacteria (from which plain bacterial vaccines are prepared), are marketed.

Many preparations made from bacteria or products from the latter are available and are being employed as aids to assist in the diagnosis of certain conditions. We have the so-called "Tuberculins." The latter are either modified tubercle bacilli in suspensions or products from the latter. They are really closely related to the bacterial vaccines. Tuberculin is of greatest value as a diagnostic agent in tuberculosis.

Preparations similar to some of the tuberculins have resulted in the introduction of the products used in the so-called Mallein and Luetin tests. The former is a test used to detect the presence of glanders, especially in animals other than humans. The Luetin test is said to be of some slight value as an aid in the detection of syphilis, during certain stages of this disease.

Most of the tests that are employed as diagnostic aids are skin tests. The preparation applied upon, beneath or between the layers

of the skin is allowed to react. During such intervals the patient is held under close observation, both as to physical symptoms in general and as to the appearance of the area surrounding the site or point of injection.

One other test worth mentioning is the "Schick Test," a skin test employed to see if one naturally possesses a resistance against Diphtheria. The preparation employed to perform this test is nothing more than a solution of the true soluble toxin from the Diphtheria bacillus.

I will finish the talk this evening in explaining to you the manufacture of modified Smallpox virus and a brief consideration of Smallpox vaccination.

The product used as a prophylactic against Smallpox is not an anti-microbic serum, nor a toxin or antitoxin, and not even a true bacterin. Its exact composition is a mystery due to the fact that the agent causing Smallpox is unknown. Inasmuch as the latter is of a poisonous nature, the term "Virus" (meaning poisonous matter) has been applied to it. Smallpox Virus (after attenuation) is the product used to create a resistance against smallpox, a disease which killed so many humans in days gone by and which is at present causing some concern to health authorities throughout the country. It is therefore advisable that this preparation should be called "Modified" or "Attenuated" or "Anti-Smallpox Virus."

Young calves (heifers, from three to six months, weighing about 200 pounds), are selected. They are kept in quarantine for about two weeks, during which time they are given rigid inspection by competent veterinarians and also tested for tuberculosis by means of tuberculin.

The calves are well fed (usually with milk) and kept under conditions as sanitary as it is possible to keep them (usually in cemented buildings, free from straw, dirt, etc., and which are washed at frequent intervals).

They are transferred to a room where the hair is clipped from the entire body. They are then scrubbed with an antiseptic solution and bathed in sterile water. They are finally removed to other quarters, shaved, and brought into the operating room for vaccination.

During the operation, every aseptic precaution is taken. The heifer is strapped securely to a specially prepared table, back down, and the exposed abdomen and inner surface of the flanks are

scrubbed, shaved again (if necessary), disinfected and finally washed with several portions of sterile water. Then, with a sharp scalpel, longitudinal incisions are made, taking care that no blood is drawn. A previously prepared virus (to which glycerin has been added) is thoroughly rubbed in. The virus, which has been subjected to rigid tests to insure purity and has been found of a high potency, is usually kept for vaccination purposes and known as the "Seed Virus."

After the inoculated material has been absorbed, the animal is removed to his quarters, where the greatest aseptic precautions are exercised to protect all vaccinated areas from contamination. At the end of from six to nine days (which time is known as the "propagation period"), pustules form along the line of scarification, in which the virus is found.

At the end of this period the heifer is again brought into the operating room, strapped on the table and generally bled to death. The vaccinated area is repeatedly washed with sterile water, so as to remove all crusts or scabs about to form, thus leaving the area covered with rows of pearly white vesicles. By means of a special instrument, the pustular material or lymph (known as "Vaccine Pulp") is removed and placed in sterile glass containers.

A thorough postmortem is conducted, and if the carcass (dead heifer) is found to be slightly abnormal from a health standpoint, the so-called vaccine pulp is destroyed and thrown away. If the animal has been found perfectly fit, thus confirming the physical and clinical examination, the pulp is mixed with proper proportions of glycerin and sterile distilled water and transferred to a specially constructed room, where it is ground into a uniform emulsion in a special grinding apparatus. It is then placed in a refrigerator, remaining here for a period of from three months to a year. During this time, all bacteria (which may get in even after observing all aseptic precautions), are destroyed or so modified that they are unable to produce disease.

After determining its activity, safety and purity tests are conducted. If found satisfactory, it is marketed in hermetically sealed aseptic capillary tubes, known most frequently as points.

All biological products are to be kept in a dark, cool place if it is desired that they retain their activity for any length of time. The potency of modified Smallpox Virus, more so than any other of

the products mentioned, is easily influenced by the variancy in temperatures.

Smallpox prevailed in all countries for many centuries. It was one of the most fatal diseases known, the average death rate in epidemics being close to 60 per cent.

Inoculation as a means of checking the spread of epidemics was practiced by the Chinese centuries before the Christian era. It consisted in the artificial transfer of the Smallpox virus by rubbing the scabs from a diseased patient into the skin of the one to be immunized. This usually resulted in a mild case of Smallpox, a quick recovery, and a lasting immunity. This same practice was later employed in Europe, but after a time it was observed that the disease itself was spread in this way and to this procedure is accredited the spread of many of the fatal epidemics.

Dr. Jenner was the first one to study this problem scientifically and in turn succeeded in artificially immunizing individuals. He observed the close relationship between a disease of cattle known as Cowpox, and Smallpox in man.

The practice today consists in introducing the modified Cowpox virus from cattle into man, thus doing away with the inoculation from scabs of human cases, where there is not only danger in the spread of Smallpox, but also the possibility of the spread of other diseases.

After extensive investigations, numerous workers have definitely proven that Tetanus or Lockjaw is not caused by vaccination against Smallpox. If infection with Tetanus does set in, it is not due to the Smallpox virus, but due to the contamination of the vaccination wound by the patient or other persons, such as may occur in the infection of any other wound which may not be properly cared for.

The vaccination of the human being is performed by slightly scarifying the skin of the arm or leg with a lancet, needle, or other scarifier and rubbing into this area by means of the sterile glass point an active modified virus. It is to be remembered that the resistance which is created does not last forever. The immunity lasts for about seven years and rarely over a period greater than ten years. A revaccination is important so as to receive again an identical benefit as obtained from the first vaccination.

ANOTHER DROP OF BLOOD.

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On a former occasion it was this speaker's privilege to dwell at some length upon a kindred subject, and to devote at that time most of his attention to the physical form elements of this important body tissue. So that a semblance of continuity may be maintained, we shall occasionally bring into this evening's presentation fragments of the former lecture. We prefer, however, in the main to focus our attention upon the less known characteristics of blood, upon the hypotheses advanced by scientists to explain certain blood functions, and upon the newer understandings of blood activities, not confining our discourse to any particular arrangement or system.

We ask you, of course, to consider the blood of which we speak as human blood, unless otherwise stated. Like every good preacher we faithfully expect to wander from our text with regularity, and carry you with us to fields quite remote from these infenced pastures. We speak of a drop of blood in the title. It is of blood, regardless of volume, that we speak throughout the lecture.

Blood is a tissue, an organ of the body, quite as distinct as the liver, or the heart, or a muscle. It is a wandering tissue so important to the economy that it can never stay long in one place, but must unceasingly travel through its sinewy canals to perform its endless obligations. It is the most vital tissue in the body.

Indeed the whole story of life lies hidden in its actions. Seek out one little cell from the myriads that silently flow through vein and artery, and in its microcosmic being is locked securely the wonderful secret of life. The mystery of Life lies hidden in action—in activity, and despite man's closest scrutiny, hidden it shall remain for many centuries to come.

Not physics, chemistry, anatomy or histology has brought us much closer home to a real understanding of Life. For when we have unearthed all basic rules and laws of physics, when the last analysis of the protoplasmic protein shall have been writ in final record, and when with the aid of microscope and microtome we shall have carried our anatomical quest to its very end, to the simple fundamental cell, we are still grappling with a relentless mystery. For even this simple

cell, a formless fragment of protoplasm, has all the earmarks of a living unit, all the essential processes of a separate vital entity. It consumes and requires food, it develops with its environment, it reproduces its own kind, it moves with predetermined direction, and strangest of all, it shows decided leanings to real sense.

Such a structureless little cell is the Vampyrell, a variety of amœba much like the white blood cell in its behavior, and labelled by the scientists the Vampyrella Spirogyra. This structureless little organism is a picky little creature, decidedly picky. It will partake only of one form of food, namely, a minute variety of algæ called the spirogyra. It can be observed on the hunt for food, stretching in all directions and creeping cautiously along in pseudopodic motion until at last it meets its quarry, when it will grasp the algæ, fix itself to the latter's overcoat of cellulose and, like a blood-sucking ferret, draw out the contents of the algæl cell. Then it disengages itself and contendedly pseudopodies on to meet its next food morsel.

Now this simple little cell will never take up with any other algæ and experimenters who have purposely placed before it other algæ, almost identical in form, have seen them always rejected. The behavior of these little unicellular simple cells in their search for food and their methods of obtaining it are so marvelous that one can hardly avoid the understanding that their acts are those of intelligent, conscious beings.

And what is true of the Vampyrell is also true of every blood cell in our bodies. Each single one of the blood cells which we see floating in the microscopic field is a micro-cosm, a world in itself, obedient to the laws of its own kind, and only functioning while Life stays home among its molecules.

But human search for Life's hiding place will continue into the long years. Science will always be asking questions, and continue to progress with its marvelous answers. Indeed not even the narrow confines of human intellect shall hinder its onward march. For human intellect itself marches onward with the years.

Out where eternity starts time was when the only life that existed upon our planet was in the infusoria that floated in the brackish shallow waters of the warm primeval seas, and we are the evolutionary products of these forerunners of all living things. The race of man will some day be as far removed from us as we are far removed from these jellied infusoria. And who today stands bold

enough to even dream of man's intellectual capacities at this stage of his evolution?

But there are those who say that even then shall the mystery of Life be sealed from man's understanding. And there are those who say that we are on the edge of tremendous discoveries. The evolutionists, the supporters of mechanistic theories of life, the fundamentalists, all seem to feel their ground secure, and even go so far as to question room for religion in their queer world of science.

But in these hectic days of argument when religion and science seem incompatible and inimical, and when theories of evolution are bandied about in puny human quarrels, it is pleasant to hear a philosopher come out of the wilderness to say, as did MacDougal recently, that evolution indeed does not destroy, but that it rather justifies, religion.

And in this connection the speaker cannot refrain from mentioning again an episode of his early Sunday school days, when his old physician teacher said that he had always been greatly fearsome of the day when some blundering, scientific idiot would come upon the secret of Life, and so bring on the whole human race the mighty wrath of a Creator whose most precious riddle had been solved by a mere creation called man.

There are those who seek to explain the processes of all vital tissues on purely mechanical lines. To these people every movement of our bodies, every concept of our minds, every leaning of our desires, our inspirations, our hatreds, our loves, our longings, our every phase of action, is inevitably governed by the ordinary laws of physics and chemistry. These are the people who predict the coming of a day when science will give a chemical formula for Life.

And science indeed is coming peculiarly close to doing this. As Vernon Kellog has recently stated: "The chemists and physicists keep pushing in on the field of the biologist; they keep claiming more and more share in the telling of what life really is, not what its joys or goal are, but just how being alive is different from not being alive."

He concludes that life is a series of balanced chemical processes, and that when this balance is disturbed by a change in environment one process goes faster than another, and then the living creature grows or decays, thrives or declines, goes on living or dies. It is all a matter of chemistry.

This is the kind of thing that keeps coming from the school of the mechanist biologists, the school that clings to the "mechanistic conception of life." Naturally, as life at its simplest is pretty complex, these mechanist biologists have not got far yet in explaining the life and behavior of human beings on a physics-and-chemistry basis, except, perhaps, they may claim to explain in some measure the fundamental factors in one's being alive at all.

We wonder, moreover, how anyone with this mechanical conception of life can explain the following fact: How can a single spermatozoon with its cell so minute that fifty millions can move freely in a drop of liquid, permit the passage of all the physical and mental peculiarities from father to son, or, by the aid of this single little cell, even skip the son and reappear clearly in the grandson?

Can laws of mechanics explain this? This remarkable potentiality in a single cell that can direct forms of motion and modes of development even unto the third and fourth generations? Yes and even transmit mental and spiritual qualities? Here indeed physics, chemistry, anatomy and histology all turn from the light and point their hopeless fingers into the night. We agree with Plato that there are many, many things too close, too intimate, for man ever to know and understand. And so we again say that the story of another drop of blood conceals in its words the story of Life.

As you sit on these benches tonight and sense the throbbing of this vital fluid through its narrow channels in our bodies, do you wonder what power or powers is responsible for its management? Do you listen to the regularity of the heart beat and marvel at the relentlessness of the procedure? And great indeed can be your wonderment, for pressed into every moment of your existence is a multitude of marvels. There is traversing now through the network of routes in your kingdoms, hosts of mighty warriors fighting every minute of their existence so that you can carry on. The precious fluid which we grossly call blood is this wandering military tissue so important to your kingdom that it can never stay long in one place, but must wander on and on, ever working for your welfare and ever fighting to insure your safety.

There are little skirmishes going on unheeded, great duties being attended to without ostentation, huge tissue building operations under way, as you are now silently listening to this discourse. One

can in a sense, compare the individual with this great old earth that unconcernedly swims about in its orbit, while in its system are millions of mortals engaged in their various capacities. Nations are embattled and men are murdered by their brothers; the farmer ploughs his fields, the birdman scouts the skies, and the poet writes his sonnets, and through it all the earth still keeps its orbit, the seasons still return in sequence, the day still entertains the sun and night is bright with stars.

But the simile falls far short for even though human life shall leave this planet and man no longer inhabit the earth, the orbit still remains, the seasons still come and go, and earth still serenely exists quite independent of human existence. But not so with the kingdom of man, for the perpetuity and sanctity of his earth depends on the perpetuity and sanctity of its cellular inhabitants, and when they collectively die man's season is over. When Life, the synchronizer of the elements, leaves the blood cell and the tissue cell, man soon begins to yield his substance to the forces of decay and the magnificent throbbing institution where Life once held court soon crumbles to a mere handful of inorganic dust. So no matter where our analysis of the drop of blood shall take us, we find Life intimately concerned in its management.

In our previous lecture we pictured blood as the military establishment of the Kingdom of Animal, a military establishment so marvelously conceived that it is perfect in every detail as long as health prevails. In the heart is its concentration camp, and it is from this central establishment that the blood cells are sent swarming upon their way to attend to their diversified duties, and as the cells traverse through the labyrinths of channels and highways sealed directions come from Headquarters located somewhere in the brain. Sealed messages we say, for no one has been able to definitely tell us the nature of the silent impulses that day in day out, through consciousness and unconsciousness, regulate the rhythmic coursing, the everlasting parading, of the vital fluid to every corner of the animal empire.

Directing this ceaseless march with unfailing precision is the General whom we call Life, and under his command the army is virile and strong, and the maintenance of its fighting and its peace-time workers goes on in silent continuity. The restlessness of this huge military organization keeps busy a vastly greater force of auxiliary workers whose business it is to supply the army with its forage,

to care for its ammunition, to provide a sanitary environment, to insure the perpetuation of its numbers, to heal its wounded, to bring in its dead, and to look after divers other phases of its activities.

So that the picture may return to us with some realism, it may not be amiss to recount the story of a battle in which these fighting forces of the body are engaged. Indeed there are skirmishes constantly going on in our bodies, where the body pays the sacrifice which must always follow victory, namely, the loss of myriads of its white cell warriors.

The little pimple, the boil, the carbuncle, are all local battles of white cell and germ. But these are only insignificant battles where only a small fraction of the blood's forces are called into action. The innumerable reserves are still untouched, for elsewhere in the body are myriads of potential warriors only waiting their chances to enter the fray, but the Commander-in-Chief and his Staff know that this is not the time for pressing the Old Guard into service. Theirs is another day and another fight.

The Battle of the Boil is but a Gallipoli, where the enemy lands and never gains headway, but is promptly forced back from the mainland into the seas of destruction.

A more serious combat, a truly great war comes, however, when the enemy strikes at the heart of the country. Consider Typhoid Fever. A harmless looking rod-shaped germ, invisible, of course, to the naked eye, finds its way, along with myriads of its kind, into the waters of a roadside fountain. A Thirsty Vacationist passing by, disregards the precepts of the sanitarians and indulges in a drink of country water "right from the spring." The little babbling brook that carries the cool water from the breast of the mountains down to the roadside fountain, runs caroming through a valley dotted with farmhouses, and murky trenches that carry the wastage and sewage of the community seep their waters into the singing brook. The brook becomes contaminated from the excretions of a typhoid patient in the farmhouse on the hill, and the deadly germs are carried into the drinking cup of the dusty traveler.

Some folks believe that the prerequisite to typhoid infection is indulgence in the waters of any old country well, and still others *know* that in every "old oaken bucket" lurk myriads of these murderous microbes. But typhoid comes only from typhoid, and the well or bucket must be inoculated or contaminated with these specific germs before they become a menace to health. And again ten per-

sons may drink of the same typhoid water and only five contract the disease. But then "that is another story." Suffice it to state that stale or stagnant water in which there sports no living typhoid germ cannot produce typhoid fever any more than a guinea pig can wag its tail.

But to return to our afflicted vacationist. The germ of typhoid which bacteriologists call Bacillus Typhosus actually slides down his gastronomic chute and through the stomach into the intestines, thence into the lymphatics of the intestine and mesenteric glands into the thoracic duct, and then into the blood stream. From there it is distributed into the organs and tissues, but like all germs it finds its particular pet locality and there it destroys its surroundings in order to establish its home. And the organism suffers accordingly. The typhoid germ particularly likes the spleen and the bone marrow, and here is where it makes its fight for territory. Here also is the reason why the body so often succumbs so readily to virulent typhoid.

When the typhoid invasion strikes, it strikes for Headquarters— it makes a bid for Paris. In the Kingdom of Animal the spleen and the bone marrow are the main preparing camps where the recruit blood cell armies assemble and whence they are diverted to the main concentration camp in the heart. So that the typhoid invaders generally make for the most important centre of blood activity. The battle is nevertheless waged with intensity and fierceness. The paucity of doughboys is balanced by the increased activity of other departments of the blood's fighting army. The white cells, the so-called infantry, are not nearly so numerous as in many other blood infections, but what they lack in numbers they greatly compensate for in valor and sturdiness.

The germs would indeed find victory easy were it not for the marvelous emergency defenses which the frantic kingdom provides. The strategy employed by the blood forces is unique and subtle, and the unwary germ, too eager in its quest for spoils of battle, overlooks the traps prepared to capture it. Chemical warfare here reaches the heights of perfection. From its entrenchments in the spleen and marrow the army of the germs streams out its poisoned darts and the blood cells in turn come back with similar weapons. Agglutins that corner the germ divisions and render them immobile and inactive, lysins that really dissolve and destroy the typhoid warriors, antitoxins that penetrate the germ wall and neutralize the internal toxins of the evil germs, and many other potent instruments of

war are used by the blood cells to paralyze the invaders of their precious homeland. And the battle wages long and fiercely.

Here not one little external promontory of the body is in danger, but the very existence of the Kingdom, and the General whom we call Life knows this full well as he commands with cunning bravery the onslaught of his well-directed troops. The Commander-in-Chief may be the Napoleon who sits on the heights watching the progress of the Waterloo that long continues to be wavering, uncertain, hesitating and menacing to both armies; the Napoleon who sends the losing army of France pell-mell into the Hell of Ohain; the Napoleon who, with victory close to his grasp, sees it fade away with Blucher's coming, and the crumbling of his trump Imperial Guard. And if the General whom we call Life, in the battle against the typhoid armies is a Napoleon—the sequel is the End of the Kingdom. The typhoid army's victory is the death of the victim, the complete end of our friend, the vacationist.

If we liken the Commander-in-Chief to the English Wellington, who sturdily fights to the last ditch, who, when the onslaught is most vicious, calls to his myriad cells—"Up, Guards, and at them"—we know then that victory comes in its own sweet time and that even though the innermost defenses of the kingdom have been menaced by the typhoid army, the kingdom still exists and that its end has not come. Our vacationist convalesces, lives and may never again have typhoid.

And so we see that attacking disease germs and conquering them by brute cannibal force is not the only mode of battle indulged in by the warriors of the blood stream. Indeed not, for the close observer of the body's military manœuvers at once finds methods of warfare ever so subtle and yet powerful, ever so delicate and yet ferocious. Blood cells do not always dispose of invading germs by the simple expedient of eating them up. They fit their weapons, their tactics and their numbers exactly according to the type of enemy they are forced to combat. The typhoid germ, a vicious scoundrel that wages war without a single scruple, does not secrete an active poison while alive and motile, but disgorges itself of the toxin when dead. So the cell fights it with certain stupefying and agglutinating devices that minimize its reproducing possibilities and neutralize the poison released when the dead germ breaks down. Diphtheria germs, on the other hand, make their landing on the windpipe, find there a

happy place to raise their children, and oblivious of the host's concern in the matter, proceed therewith to establish their permanent home. The colony grows and diphtheria germs are not particularly keen on sanitation and sewage disposal methods. So their excretions, which we call toxins, are promptly emptied into the flowing blood stream. The equanimity of the system is thus completely upset; the toxins proceed to do their deadly work, and the body works hard to combat them. Antitoxins are developed by the fighting forces of the blood, but unless Blucher comes in the form of an artificial antitoxin the germ generally comes out victorious. However, by manufacturing special anti-poisons the blood cell does its very best to fight the dread disease and uses every weapon within its power to keep the organism intact and Life still in the saddle. Only the unusual fierceness and toxicity of the diphtheria poison often makes the battle too one-sided unless the ally—horse-serum anti-toxin—is called at once to help.

And there is no better example of scientific attainment in medicine than the treatment of diphtheria with Behring's anti-toxin. But even in this enlightened day there are quacks who would belittle its value, and the same quacks tell us now that the day of genesis is at hand in the world of medicine. This is the cry of the disciples of the man of the West who measures human illnesses by electrons and cures them by vibrations. This new school of oscillopractics and vibratorians (and this is not the first school of sharks within a fisherman's ken), tells us that blood possesses certain vibratory rates which are normal for healthy blood, but which oscillate oddly for every known illness. A drop of dried blood submitted on a piece of blotting paper to one of these intellectuals is sufficient material for a vibratory analysis that will accurately determine whether the owner of the blood has cancer or diabetes, or an ingrown toe-nail. Yes, and they venture even to tell the sex and religion of the bled.

The other day a doctor bearing the fitting name of Thomas submitted to one of these super-doctors, a specimen of dried pig's blood bearing the assumed name of John Hogg (enclosing also the sum of $10, a very essential prerequisite to an accurate test), and back came the diagnosis to the effect that Mr. Hogg had a vibratory rate corresponding on the scale of diseases to an incipient locomotor ataxia, which may account for the restlessness of a certain brand of sausage with which we were recently served.

We hear on many sides of the ignorance, superstition and stand-pattism that prevail in medical practice today. Lay persons and

preachers bewail the intolerance of the fraternity of physicians who steadfastly refuse to listen to newer developments such as this electronic concept just referred to. But we can rest assured that medicine will not be intolerant to anything that will be of real worth. Medicine has to be wary. Doctors have been so often fooled with fads and fripperies that they have long since learned the lesson of the testing value of Time. The galaxy of headstones in the graveyard of therapeutic fads attest to the truth of this statement. When any new development of medicine appears on the horizon the eyes of the whole profession are turned towards it, and if in their opinion it has honest worth, they not only welcome it, they usually monopolize it, and even claim it as their very own.

Those of you who listen and are disturbed by the speaker's ridicule of these electronic concepts, need not be overly exercised, our ridicule is not meant for the theory but for the quacks and charlatans who pose as servants of the invisible empire, who have delved into the electronic mysteries of the universe so deeply that the most profound scientist cannot follow their thought, and who by their tricks and cheateries mislead and endanger the lives of the foolish victims and deluded believers who lend a willing ear to their absurdities.

We do not deny the electronic nature of the human body, for that is to deny the electronic nature of everything. Human blood, indeed, when viewed through the spectroscope, reflects its light vibrations so that when there is methemoglobin present we find certain absorption bands, and when oxyhemoglobin is present these bands occupy different places in the spectrum. But when we carry this far beyond, and say that if these light vibrations will show different bands for different chemical constituents, they will also when sensitized show different vibratory disturbances specific for every disease that affects the blood—then we take too much for granted. And that is the way with the quacks. The mere fact, however, that quacks have prostituted the electronic concepts to swell their conscienceless coffers is not hindering the legitimate inquiry into the same field of endeavor. For it is known that there are tremendous possibilities along this and kindred lines—and scientists are making rapid progress with the little potential being that they call the *electron*.

This is the tiny creature so small that it passes through solid iron walls as readily as a cootie through a Victory arch, the same tiny creatures that Marconi and his coworkers harnessed and put to work in the radio. So now in our homes, at least in the homes of those of

us who have felt the sting of the radio bug, billions of these little elec-
trons are daily employed to carry on their backs and into our ears,
messages broadcasted from all directions. And according to the oscil-
loclastic quacks, who can do so much with a drop of blood, it is this
little electron that especially whispers in their ears the mysterious diag-
nosis and cure of all the ailments of mankind.

A straw that shows the drift of legitimate investigative currents
towards the electronic oceans is the following extract from a recent
publication by Prof. W. J. V. Osterhout, of Harvard, called "Inquiry,
Recovery and Death." This book describes a new way to measure
the vitality in living things by a simple electric test. Prof. Oster-
hout finds that protoplasmic cells, which includes the blood cell—and
they are essential structures in all living things—offer considerable
resistance to the passage of an electric current through them while
they are fully alive, less resistance when they have been injured or
reduced in vitality in any way, and much less when they are dead.
By this test he has been able to measure the degree of vitality, the
probability of recovery after injury and the certainty of early death
of the cells. His investigations, however, have been made with the
cells of certain sea weeds, which after all are not so different from
our very own, for all of us have come from a sea-living ancestry. He
finds that whatever alters the electric conductivity of plant or animal
tissues, whether it be a crushing blow, too much heat, lack of air, lack
of water, presence of poisons or anything else injurious, will impair
or shorten the life of the organism. But for all his scientific ability,
Prof. Osterhout does not overestimate the value of his work. He
appreciates its limitations. He knows that tomorrow is the day of the
electron, and that there is too little known about it today to justify any
prediction or prophecy as to its ultimate possibilities and potentiali-
ties. Only the quacks claim to have harnessed it today, and in their
hands the little electron is abused and paraded before gullible neu-
rotics as a means of diagnosing and curing the ills of all mankind.

But " 'twas ever thus" and the charlatan has never missed an
opportunity to use the legitimate means to an illegitimate end. Very
recently a pseudo-scientist in the Middle West earned himself much
subtle advertising by announcing in the newspapers that he was ready
to demonstrate the paternity of a young child, about whose person a
loathsome and scandalous court suit had been instituted. One drop
of the child's blood, a drop of the blood of each of the parents,

was all that this man said was necessary to establish without doubt the legitimacy of the issue.

A *bona fide* scientific inquiry into this subject, however, does not afford any specific test that might be used to this end. It is admitted, in blood typing, that the specific agglutinogens never appear in the offspring unless they are present in the blood of one of the parents, and what is really inherited then is the presence or absence of the several agglutinogens. This fact has led to the establishment of certain algebraic formulas which may be worked according to a dihybrid Mendelian scheme, and whereby the blood type of a parent may be established from the blood type of the offspring and of the other parent. But this test is entirely too hypothetical to stand the cold-blooded investigation of a thinking court. So science is still working at it, while the quack is braying and finding a responsive audience.

We come now to the part which is played by the much advertised and much misunderstood endocrines or gland secretions. Situated here and there in the blood avenues are little factories called the ductless glands, and into the passing currents of blood these tiny mills pour out their precious products. The chemical substances delivered into the blood stream by these glands affect every cell in the body. Their secretions with their influence upon the brain and nervous system, as well as every other part of the body corporation, for they are essentially blood-circulating chemical substances, have been discovered to be the sole arbiters of our several attributes. They determine our temper and temperament. Tall or short, bright or dull, thick or thin, it's their decision. They curve our figures, cut our wrinkled lines and dominate our characters. A sprinkling of this hormone and a dash of the other is the only difference between the cavalier and puritan, the polished scholar and dull buffoon, the crude costermonger and the wizard of finance.

And oddly enough modern knowledge of these chemical substances in the blood dates back scarcely half a century. But already the paths blazed by the pioneers in the quest are leading straight to marvelous lands. The thyroid gland, the thymus gland, the adrenals, the pineal, have all yielded great secrets and will continue to yield more as the years go on.

The ductless glands have been described as little chemical factories with an intricate system of cellular departments. To these factories the red cells of the blood convey the crude products which are promptly put through the retorts and furnaces of the glands, and

are changed into the complex chemical substances which we call hormones. These hormones are then broadcasted back into the blood stream and minister with varying effect upon the tissues of different parts of the body. The pituitary gland plays directly upon the brain cells, the suprarenals work first upon the heart, and so on.

In the neck region is the thyroid gland, a factory producing a chemical called Thyroxin. This chemical and its related compounds have a specific function in the body. They control the energy production of the machine as well as the growth of certain organs and tissues. This is particularly true of the brain. From another viewpoint the thyroid factory may be looked upon as supplying the body with its uniform quota of iodine, that important elemental constituent that seems to exercise such a profound influence upon the animal economy. This gland, when it is working sanely, liberates just enough iodine out of the crude products which come into its factory, so that there may be maintained in the blood just about as much iodine as there is in sea water. Ever since we have evolved out of the jelly fish that lazily tossed about on the crest of the salty ripples, Nature has decreed that we should not be lifted too far from our humble infusorial grandparents, and so instead of the sea water floating about us, it now reminds us of its importance by floating inside us. Indeed our very blood is nothing but sea water, to which has been added a little hemoglobin as an oxygen-carrying pigment to supply the far-off cells that are out of atmospheric contact.

The abnormalities caused by an overworked or an underworked thyroid gland are too numerous to mention here, but there has leaked into the lay mind an erroneous idea that all fat persons are fat because the thyroid has closed down its factory. Patent medicine vendors have played up this idea and they now offer to the unwilling fat carrier a remedy which they claim will harmlessly but surely melt off the excess fat without discomfort to the erstwhile carrier. These obesity "cures" all contain the thyroid gland of an animal, and they work by activating the body fires so that the fatty fuel is burnt off. Danger comes, however, in that the fire that consumes the fat also hurts the other body substances such as the protein, which takes so long to organize and knit together. Thyroid should not be self-administered—it is much too potent a medicine to place in lay hands. Even the doctors hesitate to use it, just for reducing physical ponderosity. They know that not all fat persons are fat because of thyroid shortage. Does not the poet sing that

"Some grow fat with faulty fare,
And some grow fat with laughter"?

The pituitary gland is a tiny laboratory resting snugly in the centre of the brain. So important to the human machine is this gland that the great Designer placed it inside a bony couch within the bony skull, a sort of a double protection as it were. It is divided into two manufacturing departments, one, the posterior plant, building up a chemical substance called tethelin; the other manufacturing a very important compound called pituitrin, both of these chemicals now largely utilized in medicine. This gland as a whole has no small task to perform, for its activities are said to control the consumption of body energy, just as the thyroid controls its production.

The poetic Berman, whose excellent and picturesque book on the glands is now a standard, also blames the pituitary gland for being the laboratory whose flasks and crucibles turn out that all-important human emotion called love. He dares to give Love a chemical formula. So many O's, so many C's, so many N's, but no I's (for Love was always blind). All through the animal world, says he, in the springtime, when the sleeping pituitary reopens its plants and increases its products in the blood stream, emotions of love are provoked, and all the world goes wooing. When the nightingale warbles and the mocking bird gurgles, when the robin fills its scarlet breast and the starling floats in ecstasy through the perfume-laden air, all are calling for their mates, and all because of love—love in the blood—manufactured unconsciously by a few hidden cells. The calf-like symptoms of love have long been known, but the chemistry of its toxins is still a pretty hypothesis.

Sitting astride the kidneys is the bi-departmental adrenal gland. Out of this factory comes the subtle product called adrenalin, perhaps the best known of all the internal secretions. This substance largely controls the whole body balance. Hypothetically the adrenal gland is the central establishment in the gland chain of factories. It energizes, stabilizes and synchronizes the efforts of the other plants. It is also said to fit the body for emergency situations, to "stiffen up the sinews and summon up the blood."

The Thymus gland, clinging to the windpipe, is the gland of childhood. It is the gland whch keeps children children, and whose activities prevent the too rapid maturing of the young. After pu-

berty this gland becomes atrophied and disintegrates, and its disman-
tled laboratory no longer pours its substance into the blood. Thus
Youth comes only once and the poet knew this full well, as he
sang:

> "For when youth the dream departs
> It takes something from our hearts,
> And it never comes again."

The parathyroid glands are situated in the neck behind the
thyroid glands. Their output largely controls the mortar and
cement business of the body, the calcium metabolism. They also con-
trol the excitability of the nerves and muscles.

The pancreas is now considered a gland of internal secretion.
Its chemical product, called insulin, has been lately isolated and
promises revolutionary results in the treatment of diabetes. Insulin
is really not a new discovery, for it has been long known theoret-
ically at least, as the controller of the sugar metabolism of the body.
Only its separation and isolation, as well as its specific use in the
treatment of disease is novel.

In medicine this might be termed the endocrine period for the
doctors are putting to test without mercy the old Hahnemannian
concept, *Similes curantur similibus*. Nearly all human ailments are
blamed on some over- or under-functioning gland, and to com-
bat the deficiency or excess the respective gland product for a lower
animal is used. Some good results are obtained, but on the whole
the business is still a fad, and may have worked more harm than
good, for there is no one to judge. It is all a matter of empiricism.

Now comes the chemist and tells us with definiteness all of
these gland secretions are only chemical compounds which can be
duplicated with products made from coal tar and its various deriva-
tives. Pretty soon he claims he will duplicate them all, and then a
gland that fails to function right will lose its place and right to
serve. So we can now hope for the day when we will carry a
vest pocket case containing the chemist's supply of compressed
hormones and thus regulate at will our varied passions. Until then,
however, we must depend upon the stock yards to supply our func-
tional deficiencies with crude and empiric extracts of glands from
pig or cow or gentle sheep.

Or perhaps we may turn to the newer fashion of excising a
gland from some forlorn lower animal and replace our activeless
gland with this foreign implantation, or perhaps we may, from a

brother of our own race, purchase his birthright glands for a mess
of golden pottage and so hope to bring back to us fair youth and
fire. Unfortunately, however, these experiments are lacking in
good results when tried on man. Implantation from the anthropoid
apes works best, and thus another brick at Bryan. In all cases,
however, the relief is only temporary, and the borrowed gland
promptly succumbs to the same influences that rendered impotent the
natural, original organ. The Elixir of Life is still unanalyzed, and
the Fountain of Youth is still at the foot of the rainbow.

That the endocrine gland has also made an impression on our
national literature is shown by the following quotation of a bit of
verse from that satirical institution called *Life:*

A Modern Gent to a Modern Lady.

If some day I beam on you
    And gently squeeze your hand,
It's 'cause you've proved attractive to
    My pituitary gland.

And if I whisper in your ear,
    " 'Mong roses you're my bud,"
It's not because I love you, dear ;
    It's adrenal in my blood.

And if I trust you with my life,
    And pen you throbbing lines,
Don't think I want you for a wife—
    I just lack vitamines.

So that no one of us may carry away too exalted an opinion of
oneself the following data, which originally appeared in an insurance
journal, may serve the purpose well. The nursery rhyme used to
teach us that we are made of "scissors and snails and puppy dogs'
tails," or "sugar and spice and everything nice." Not so with chemis-
try, however. Here is the total humorous composition of the crea-
ture called man : Fat enough for seven bars of soap, sugar enough to
sweeten two cups of Child's coffee, lime enough to whitewash a cel-
lar around the bottles, phosphorous enough to make four boxes of
matches, magnesia as much as the druggist sells for a nickel—and
that is not much—iodine enough to paint a pimple, and sulphur
enough to rid a dog of fleas. Many items in this estimate are left
largely to the imagination, such as the size of the dog and the number

of his tormentors, but the total cost is given, *a la* Lit, as 98 cents, which is neither expensive nor calculated to foster conceit.

Luden has, however, called attention to the fact that "in physiology we get so close to the details that we obscure the whole, so close to the forest that we cannot see the woods for the trees. These quantitative facts regarding the body's make-up are somewhat startling. For example, the entire volume of circulating blood, which about half fills an ordinary bucket, contains only a small teaspoonful (from 4 to 6 gm.) of sugar and a tablespoonful (32 gm.) of salt. When we consider the minute variations in the sugar content that the modern chemist can measure in a few drops of blood, we gain added respect for the science of quantitative analysis. The iodine in the entire blood amounts to but .001 gm., or an average dose of atropin. When the physiologist tells us that adrenalin can be detected by biologic methods in a dilution of 1 :330,000,000, it means far less than to say that it is equivalent to diluting 'a small glass of whisky (10 cc.)'—a very small glass, that—into the contents of 1320 city street sprinkling carts, which would form a procession about six miles long. We all know that the normal blood contains about 5,000,000 red corpuscles in each cubic millimeter, but do we all realize that the entire blood must therefore contain some twenty-five trillion red cells and thirty billion white cells, figures that have an astronomical aspect? If mental pictures of the billions and trillions of blood cells crowding, jostling, and possibly struggling for a share of the mere teaspoonful of sugar in the total blood volume of a full-sized man, or the endless procession of sprinkling carts representing the adrenalin concentration to which animal tissues respond, appeal to one's sense of humor, they also do much more than this : They bring home the delicacy of the adjustment by which the human body mechanism is regulated ; the extent to which this fine adjustment may be disturbed by seemingly trivial factors ; the obligation of both laymen and physicians not to ignore the 'slight' tokens of distress of the body engine." And the regard which we must all have for the Infinite Mind, whose eye is on the sparrow and who also watches us.

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THE ROMANCE OF SPICES.

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> "Nose, nose, nose, nose!
> And who gave thee that jolly red nose?
> Sinamint, ginger, nutmegs and cloves;
> And that gave me my jolly red nose."

The foregoing doggerel from a sixteen century author is proof, not only of the unchangeableness of human nature in its efforts to avoid responsibility, but it brings into prominence a group of spices which have been the cause of centuries of bloodshed, of great maritime discoveries, of changing boundaries and the rise and fall of empires.

It is more than probable that gin rather than ginger was responsible for the roseate condition referred to, but that has nothing to do with the present lecture.

When and by whom the first spices were employed to give zest and flavor to food will ever remain an unsolved mystery, for their use antedates all historical and traditional records. In all climes and in all ages man seems to have needed some pungent or aromatic food accessory. The substances now included in the list of spices is surprisingly large, comprising many vegetable products and a number of aromatic herbs.

A small group of these, nearly all of them products of the mysterious East, where civilization's cradle was rocked by the stern hand of destiny, have come down to us through the ages, set apart from the others by the human interest bound up in their story—a story which has never been and can never be fully told. A story in which we find "weaving through all the poor details and homespun warp of circumstance a golden woof thread of romance."

Back to far Cathay we go for the glimmering of the earlier chapters of this story, back to the jungle-buried evidences of long-forgotten civilizations of the Orient, for it was out of the East that there were transported, first by junk and caravan, later by felucca, galleon, caravel and carrack, then by merchantman and clipper, and now by ungraceful freighter, these aromatic and pungent wares that have left their indisputable traces on the politics and geography of the world.

(83)

The very names of the earlier kingdoms and cities are no longer known to us. Even the poets can give us only glimpses through the medium of dreams, as we remember Coleridge's sonorous lines of that former ruler of Cathay:
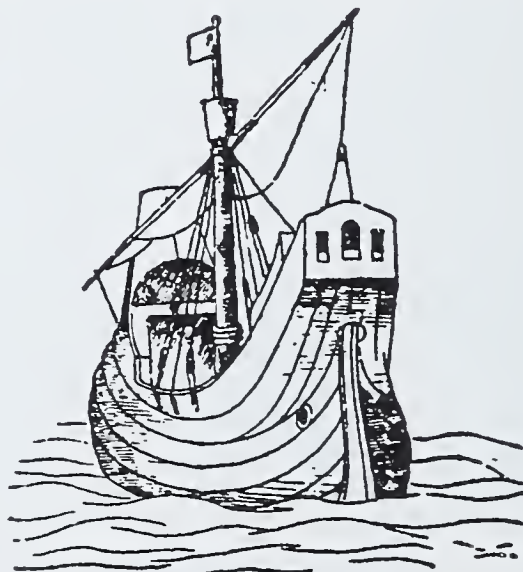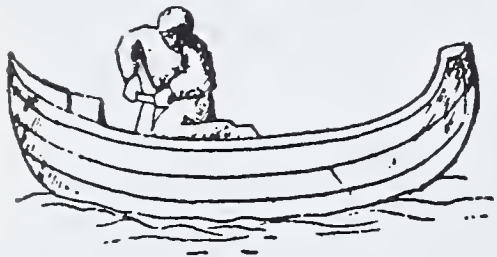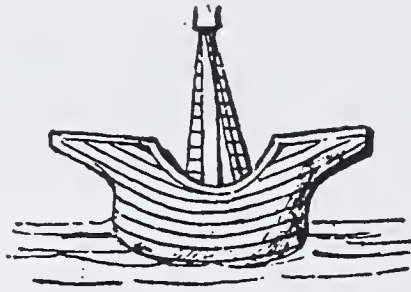
Types of Merchant Ships.

> "In Xanadu did Kubla Khan
> A stately pleasure dome decree;
> Where Alph, the sacred river, ran
> Through caverns measureless to man
> Down to a sunless sea."

Kingdom succeeded kingdom, empire succeeded empire, and still we are able to discern only fragments of the tale. Babylon was eclipsed by Tyre and Sidon. Alexandria, Syracuse, Carthage—all bowed to Rome. Constantinople's greatness was eclipsed by that of Venice, which was in time supplanted by Lisbon, and this in turn gave way to Amsterdam and London as centres of the spice traffic.

Tithes of anise and cumin are referred to in biblical times, although these were not counted among the precious spices. In Egypt, caravans from before the days of Tut-Ankh-Amen had traversed the burning sands with their spice laden camels. Joseph's jealous brethren sold him to such a caravan and the effect upon the history of Egypt was of great moment.

When Alaric the Goth conquered Rome in 408 B. C., one of the ransoms asked by him was 3000 pounds of pepper, then worth more than its weight in gold. In the time of Augustus Caesar, one of the records reads: "Unto the East, under the rising sun, to fetch rough pepper and pale cumin seed for Roman wares."

Prior to the thirteenth century all trade routes from the Orient were overland and heavy toll was taken by those who occupied the gateway of the then civilized world. Moorish merchants in the thirteenth century, brought far Eastern products by way of the Arabian and Red Seas to the port of Suez, thence by caravan to the Nile and down the Nile to Alexandria, where, as has been aptly stated, "East touched West and the Christian and Mohammedan worlds met." Balsun, on the Persian Gulf, and Mocha, on the Red Sea, were caravan starting points from the earliest period of which any record exists.

In the beginning of the fourteenth century Edward of England had granted privileges to merchants under the "Charta Mercatoria," in which were mentioned "spices, gross spices or groceries, as well as minor spices." A little later in this same century the "Fraternity of Pepperers" changed its name to the "Guild of Grocers," and among other objects depicted on the coat of arms were six cloves. The

grocers of this day were the merchant adventurers who sold in large lots, while the pepperers sold in small parcels.

In the early part of the fifteenth century we begin to get a connected story, so we shall take this as our starting point. Venice, which had been founded in the fifth century by the fleeing hordes of Attila the Hun, had gradually acquired the commercial supremacy of the Mediterranean, her only rival being Genoa. When, in June of 1380, the Genoese fleet was destroyed by that of the Venetians, she entered into what is now recognized as the greatest century of her development.

Marco Polo, in the previous century, had helped to lay the foundations of her power by his extensive travels in the Orient. It is quite possible that his valuable knowledge would not have been made available to his contemporaries had he not taken advantage of a year's detention as a prisoner by the Genoese, in 1298, to dictate his marvelous experiences to a fellow prisoner, who later gave them to the world.

Venice was built upon the sea; thrived and was dependent upon the sea. The later crusaders took advantage of her position and used Venice as the embarkation point, thus giving her a prominence which was used to great advantage in the development of her commerce. The mercantile and warehouse records of these early centuries show the traffic in pepper, cinnamon, nutmeg, mace, cloves and ginger, to have been worthy of special mention, and this comprises the list of the more precious of spices, and those whose particular history we are about to follow.

At her peak of affluence it is estimated that the Venetian traffic in spices alone amounted to over ten million dollars annually—a notable sum for one small city in those days. At this period there were afloat upon the Mediterranean and up along the west coast of Europe to London and Bruges, more than 300 great galleys or argosies (named from Ragusa, a nearby Dalmatian seaport where these vessels were built) and for their protection she owned forty-five war galleys.

The Rialto was then the centre of the commercial life of Venice. This is a mercantile exchange built upon an island of that name. Here gathered the money lenders and merchants of Lombardy, Navarre, Tuscany, Bavaria, Hungary, Florence, Catalonia, Germany, Brabant, England and Flanders. Here Shakespeare makes Shylock hear the news of Antonio's ventures. Rich man, poor man, beggar

man, thief, doctor, lawyer, merchant chief—all commingled in enterprises of great speculative possibilities.

The foreign merchant in these days was subjected to humiliating and severe restrictions. He was required to live in a warehouse-hotel, constantly under the supervision of officials who saw to it that neither the State nor local merchants were cheated. He might trade with none but Venetians and must dispose of his entire stock, even if at a loss.

The merchandise to and from Germany was transported over Alpine snows by heavily guarded pack trains. Western Europe and England were served yearly by fleets of galleys—Flanders galleys, they were called. Each was rowed by 180 oarsmen, protected by archers. Among the ports of call were Pola, Corfu, Alicante, Almeria, Cadiz and Lisbon. The terminus was Bruges, where merchants of the Hanseatic League and of the Fugger's, took charge of further distribution. Some few galleys reached London or Southampton.

The wrecking of a richly laden argosy off the coast of France in 1578, led to the declaration by the Venetians that they would no longer send their vessels into such dangerous waters and this led indirectly to the establishment of the far-famed Levant Company of London.

Venice was a typical merchant republic. Her young patricians were sent on Flanders voyages to serve their apprenticeship to commerce. The grateful acknowledgment which the Venetians accorded to the sea as the giver of prosperity was attested by the famous annual ceremony of the symbolic marriage of the Doge to the Adriatic, a golden circlet being tossed into the sea with these words: "We espouse thee, O sea, as our bride and queen." Some few of San Marco's sons wandered far afield and even penetrated Muscovy with their rich consignments of merchandise and spices.

Spices were so precious and so expensive in Europe in the fourteenth century, due to the long overland caravan routes and the many who took toll in profit or tribute on the way that the thought of western merchants reaching the Oriental source of supply and thus reaping the entire profit, became an obsession which lasted until the problem was finally solved by Vasco da Gama in 1498.

We are apt to look upon these early navigators as imbued with the spirit of adventure alone, but their heroism had ever a background of selfish interest, and the voyages of Columbus, da Gama,

Magellan, the Cabots, Vespucci, Sir Humphrey Gilbert, Drake and others had for their primary object the discovery of a direct route to the Spice Islands and the control of the trade for the sovereign who financed the expedition. The fabulous northwest passage and its mythical northeast counterpart were but possible means to a selfish end. There was an unverified tradition that the Phœnecians, whose keels had traversed the Mediterranean 2000 years before Christ, had discovered an all-sea route to the Indies by sailing westward out of the Strait of Gibraltar.

The Portuguese, those intrepid sons of Lusitania, had long been noted for their maritime courage when Venice commenced to dominate the commerce of Western Europe. Early in the fifteenth century, Prince Henry, the third son of King John of Portugal, had dreamed of discovering a water route to the Indies. Prince John, returning from a visit to Venice, brought his brother Henry a copy of the complete works and maps of Marco Polo, then over a century old, but never put to practical use. This served as an inspiration to his dreams and thus the Venetians contributed unwittingly to their own downfall by permitting the dissemination of this information.

In furtherance of his ambition, Henry established headquarters upon an estate on Cape St. Vincent, the southernmost point of Western Europe. Here he surrounded himself with navigators, cartographers and mathematicians. Although he never made a voyage himself, he sent out an expedition each year for more than forty years, beginning in 1418.

At the time of his death in 1460 much had been accomplished, for the Cape Verde Islands, the Azores and the Canary Islands had been discovered, and more than one thousand miles of African coast line had been charted and explored.

Pope Martin V, in order to aid this laudable undertaking, had granted plenary indulgence to all who perished in exploration or conquest, and had, in addition, promised that the Portuguese should retain all the lands that might be discovered.

One of the less important spices, known as the Grains of Paradise, or Melegueta Pepper, which had hitherto been brought overland from tropical Western Africa, became the monopoly of the Portuguese crown, due to the expeditions sent out by Prince Henry, and the interest in the search for the Indies became intensified.

In 1486 an expedition sent out by King John, commanded by

Bartholomeu Dias, a gentleman of the royal household, reached the southernmost point of the African continent and, being buffeted severely by the storms prevalent in this neighborhood, Dias named it Cabo Tormentosa, but upon his return, King John, seeing the importance of this discovery to future voyages, rechristened it Cabo Bona Speranza, or Cape of Good Hope, which name it still retains.
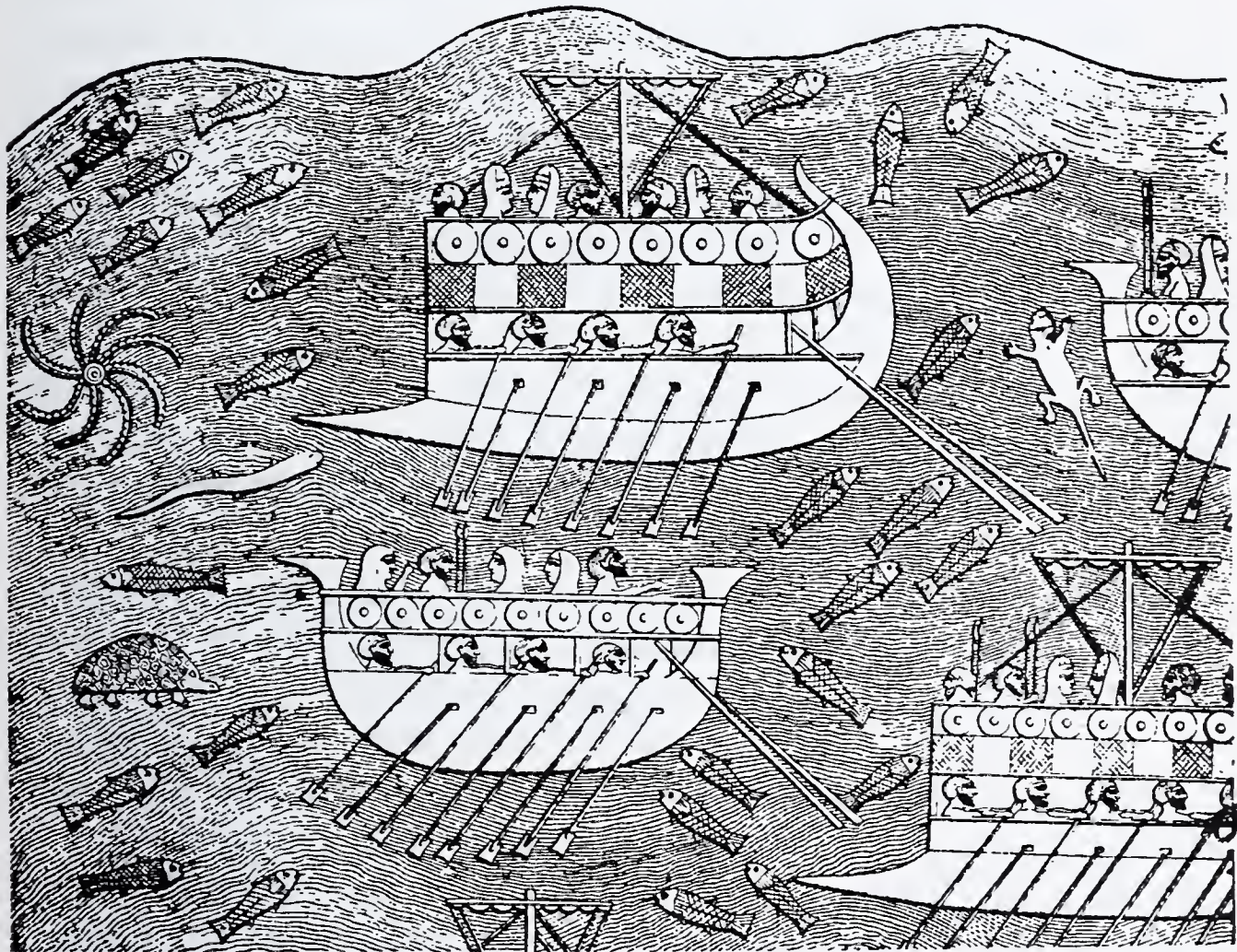
Phoenician Ships (About 700 B. C.).
From a Relief in the Palace of Sennacherib.

About this same period King John sent overland emissaries to the Orient to bring back information concerning a possible sea route and facts regarding the spices themselves, for their actual origin had been shrouded in much mystery. His first messenger failed through a lack of knowledge of the Arabic language, for it will be remembered that it was the Moorish merchants who controlled the land and sea routes east of Suez. Two other emissaries, Pedro Covilham and Alfonso de Payva, were then sent out with orders to trace the Venetian commerce in spices through its Moorish contacts to the original sources themselves.

The land of Prester John was also to be located and visited. This fabulous Christian monarch was believed by some to have established a powerful empire, somewhere beyond the desert. Marvelous tales were told of his power and wealth and letters purporting to have been sent by him to Western rulers were in existence.

Covilham and Payva went to Alexandria, thence to Cairo and by caravan to the Red Sea, where they met Moorish traders newly arrived with spices from India. At Aden they separated. Covilham went with a Moorish merchant ship to Calicut on the Malabar coast of southwestern India, being the first Portuguese to voyage on the Indian Ocean. Here he saw pepper and ginger growing and obtained information concerning cinnamon and cloves.

Upon returning to Egypt he learned that his partner, Payva, who had started for Abyssinia, had been murdered. Covilham sent the report of his Indian voyage to King John by messenger and remained in Abyssinia to complete his companion's task. Here he made himself so useful to the monarch of that land that he stayed there until he died, serving his native land, meanwhile, by frequent reports and correspondence.

During this period the famous Genoese navigator, Christopher Columbus, had made his first voyage across the Atlantic in search of the same goal on behalf of Spain. The voyage of Columbus in 1492 might with propriety be called the most successful failure in all history. It has little to do with our story except that it kindled anew the hopes of the Portuguese in connection with the African coast route. Columbus died in ignorance of the fact that he had not discovered the far-famed Indies. He had started for Cathay, and his navigating instincts were sound, but he did not realize that a new continent interrupted the passage between him and his goal. His discovery may be most aptly termed the most valuable by product of the search for the Spice Islands.

In 1495 Manuel (called by historians "the Fortunate") succeeded John II as King of Portugal and decided to carry on the exploration policy of his two successors. Seldom in history has continuity of effort been exhibited in a greater degree. For more than three-quarters of a century these three Portuguese nobles had followed a line of endeavor which had brought some valuable results, the main object still being unattained. But success was just beyond the threshold.

In 1497 Manuel selected a well-known Portuguese navigator,

Vasco da Gama, and placed him in charge of a small fleet of three vessels which sailed from Lisbon in June, and which rounded the Cape of Good Hope in November of the same year. They reached Mozambique a few months later, but the ruling sheik showing evidences of treachery, da Gama continued his journey up the east coast of Africa, arriving at Melinda on the Zanzibar coast. Here he was advised to await favorable winds for the continuation of the journey to India, for which the king of Melinda, being favorably impressed by da Gama, provided two experienced pilots, the third vessel of da Gama's fleet having been abandoned somewhere on the east African coast after salvaging all stores and metal parts.

The two Portuguese vessels left Melinda in July, 1498, and reached Calicut in India about a month later. The Moorish traders, much surprised at the arrival of the Portuguese vessels, tried to interfere with their traffic with the Indian natives, but the Portuguese having, in addition to gold and silver coins of the Portuguese realm, abundant stocks of coral, copper, amber, quicksilver and vermilion, all in great demand by the natives, had no difficulty in establishing mercantile relations.

These were the days of relative rather than actual values. Shrewd bargaining was the order of the day and no transaction was considered to be successful unless each party believed that he had outwitted the other.

The first cargo that da Gama took back was composed of pepper, cinnamon and ginger. He did not insist upon keen bargains being driven by his agents and accepted without question even low grade stocks of these spices. He was wily enough to realize that if he arrived safely at Lisbon with any cargo of spices, thus demonstrating the feasibility of such voyages, the subsequent expeditions would be amply equipped to take care of Portuguese interests, which proved to be the case.

The Moors continued their trouble-making efforts while da Gama's vessels were loading and even succeeded in having him imprisoned for a time, an indignity which he bore with surprising mildness, as he realized his helplessness if he offered armed opposition. He finally set sail for home, secretly vowing vengeance upon both Moors and natives, which vows he kept in a terrible manner, as we shall soon see. On the homeward voyage he made several stops, one at Melinda, where he exchanged presents with the king, who sent a letter of friendship to Manuel written on gold leaf.

On September 18, 1499, he arrived in Lisbon and was greeted by the king and the inhabitants with great demonstrations of joy. He was immediately rewarded by having the noble title of "Dom" conferred upon him, and was further presented with 20,000 gold pieces, besides being accorded other emoluments and privileges. The voyage had paid a sixty-fold profit to those who had financially sponsored it, so great generosity was also shown to the captains and mariners, who in addition to other rewards "were each given ten pounds of spices for their wives to divide with their gossips and friends."

In the meantime Venice had gone ahead serenely, in ignorance of the doom which was awaiting her commercial supremacy. When it became known on the Rialto that Portuguese vessels, laden with Indian spices, had successfully returned to the harbor of Lisbon, great consternation was shown. The Venetians were in a peculiarly difficult position. They had the vessels and the sailors to follow the same route as the Portuguese, but they were deeply involved in Alexandria, where they carried immense surplus stores, and they feared these would be sacked by the Egyptians if they followed the Cape route themselves.

In their chagrin, the Venetians even went so far as to incite the Egyptians and Moors to co-operate with Indian potentates to attack the Portuguese expeditions, but without avail. The immense profits of the Venetians were gone, never to return, and the subsequent mercantile career of this Italian republic was concerned only with the distribution throughout Europe of the spices which the Portuguese brought to Lisbon, for strangely enough, the latter never seemed to care for the profits beyond the original handling, and this indifference was eventually to cost them the loss of the entire trade, as we shall see.

In 1500 the Portuguese king sent out a fleet of thirteen ships under Pedro Cabral. This fleet was blown out of its course and scattered to the westward, some of the ships reaching Brazil. Only six vessels of the fleet reached India. Here they had difficulty with the Moors, to whom they gave a foretaste of Portuguese severity by seizing and destroying several Moorish vessels after transferring their rich cargoes to Portuguese ships. Cabral established friendly relations with several Indian potentates and left agents or factors at a number of places. He returned safely to Lisbon heavily laden with valuable spice cargoes.

In 1502 da Gama was sent out with nearly a score of caravels. With the daring of his race he shortened the time of his voyage, after rounding the Cape, by striking boldly across the then uncharted Indian Ocean. Upon his arrival in India he sent the following characteristic message to an Indian potentate whom he encountered:

"This is the fleet of the King of Portugal, my sovereign, who is the lord of the sea, of all the world, and also of this coast, for which reason all of the rivers and ports which have got shipping have to obey him and pay tribute, and this is a sign of obedience— neither trading in pepper, nor bringing Turks, nor going to the port of Calicut. For any of these three things, the ships which shall be found to have done them shall be burned with as many as shall be captured in them. Let the King send me an answer. If it be not a good one, I will send and burn ships and town and cause much harm to be done."

It will be seen that the first steps taken by the Portuguese were to secure an absolute monopoly of the spice trade. On this same voyage da Gama captured a richly laden Moorish vessel, transferred the cargo to his own vessels and burned the captured vessel with its crew and passengers of several hundred living souls. Among the passengers were wealthy Moorish merchants from Egypt, who pleaded with da Gama for their lives, offering as a ransom to fill all his vessels with pepper if he would but set them safe ashore at Calicut. With fiendish heartlessness da Gama refused their entreaties, in spite of the advice of his own officers that he assent.

This was but a mild beginning of the satisfaction of the terrible desire for vengeance which seemed to fill da Gama's soul and which makes him one of the most atrocious characters in history. Other vessels bound from Coromandel to Calicut fell into the hands of da Gama. After plundering them, the unfortunate mariners were bound, their hands, ears and noses cut off, their teeth crushed in, and their bleeding, writhing, living bodies loaded into one of the captured vessels, which was then fired. The severed members of the victims were loaded into another ship and sent ashore as an object lesson to all who should, in the future, question Portuguese authority.

Upon this voyage, da Gama left a trail of trading stations with agents in charge, supplied with stocks of goods for barter.

Portuguese expeditions now followed each other in rapid succession, each year seeing a score or more of vessels returning to Lisbon with profitable cargoes. The policy of the Portuguese

was not to annex territory but to establish numerous factories or trading stations and to destroy the commerce which the Moors had controlled for centuries without interference. Vasco da Gama, now Count of Vidigueria, made but one more voyage, many years later, in 1524, and died in Goa in December of the same year.

Meyerbeer's opera "L'Africaine" concerns itself with da Gamas' earlier voyages and the stellar role is that of the Portuguese hero.

In 1505, Francisco de Almeida was appointed first Viceroy of India and sailed from Lisbon with more than a score of vessels. He was authorized to establish trading stations and build and garrison forts, which was done. The most prominent name associated with the establishment of Portuguese power in India was Alfonso de Albuquerque. It was he who gained Ormuz, the port which controlled the traffic of the Persian Gulf, for the Portuguese. It was Albuquerque, too, who conquered Goa for the Portuguese. Goa, the one-time capital of India, whose regal splendor and untold wealth has long since departed, is one of the footholds in Asia still retained by the Portuguese. This is a fact surprising to many who believe that the whole of India is under British domination.

Goa was for many years the official residence not only of the Portuguese viceroy of India but of the King's Counsel and the Archbishop as well. The Viceroy held office for three years, but according to Linschoten (a Dutch traveler who plays a prominent part later) the term was too short for the incumbent to do much important work for the King. The first year, says Linschoten, was occupied in learning the manners and customs of the country, the second year in amassing a fortune upon which he could retire, and the third year in getting his accounts in order so that his successor might not find him a defaulter.

The Portuguese under da Gama, Almeida, and Albuquerque, having established themselves satisfactorily on the Malabar coast of southwestern India, commenced to realize that many of the spices were coming to them at second and third hand, for pepper and ginger were the only spices actually grown in this section. Cloves, nutmegs, mace and cinnamon came from points still further east, in some cases thousands of miles.

To give an idea of values and possible profits at this time, cloves may be taken as an example. A bale of cloves (500 pounds) was worth two ducats (about $5) in the Moluccas, the country of their origin. It was worth fourteen ducats by the time it reached

Malacca, and 500 ducats in Calicut, an increase of over two hundred fold. At this period it was worth nearly 2000 ducats in London.

The Portuguese also learned that the Moors were carrying on a trade in these spices between these far eastern isles and the Red Sea ports, without any contact with India. This could not be tolerated. In 1505 Almeida had reached Ceylon, the land where the finest cinnamon grows. In 1509 he had obtained a foothold in Malacca, more than a thousand miles to the eastward, and in 1511, Albuquerque's ships had skirted Sumatra and Java and reached the Banda Islands, then the source of the world's supply of nutmegs and mace, and which were a thousand miles beyond Malacca.

The Molucca Islands, or clove islands, as they are called, because they were the only spots in the world at that time where the clove tree was found, and which lay several hundred miles north of the Banda Islands, were reached by the Portuguese in 1512. The Por-

Roman Cargo Boats Being Loaded at a River Landing.
(A Section of Trajan's Column.)

tuguese were the first Europeans to arrive at this tiny spot, which was to cause centuries of strife between Moors, Portuguese, Spaniards, Dutch and English, in which strife the islanders themselves were exterminated and the clove trees uprooted and destroyed, for all the clove trees at the present time are in plantations in other

parts of the world. The tree does not exist, even in the wild state, in its original habitat.

In 1513, Albuquerque captured Malacca and obtained for his sovereign a pledge of amity from the King of Siam. Shortly after this the Portuguese tightened their grip on the commerce of the Indies and were in virtual control of everything from the Cape of Good Hope to the Moluccas. This monopoly lasted for nearly the whole of the sixteenth century, which was the zenith of Portuguese power and commerce.

Portugal had also gained a foothold in China during this century, for the far-famed products of Cathay, silks, perfumes and spices, had been carried by caravan for centuries across the entire Asiatic continent to the Caspian or Mediterranean Seas. A few Chinese junks had traded with the Moors at Malacca, but all of these routes were expensive, and for more than a thousand years rhubarb, of which China was the sole source, was the most costly drug in Europe.

During this century of Portuguese control the natives of that country who established themselves at the forts or trading stations, lived like Oriental princes, surrounding themselves with slaves and enjoying luxuries of every description. Jean Baptiste Tavernier, a seventeenth century author of Travels in India, refers humorously to "Hidalgos of the Cape," referring to the practice of many Portuguese of mean birth who prefixed "Dom" to their names on rounding the Cape of Good Hope on the outward trip.

Shortly after the discovery of America by Columbus, Pope Alexander VI had attempted to divide between the crowns of Spain and Portugal all of the lands that had been or were yet to be discovered. The dividing line was a meridian passing through a point 100 leagues west of the Cape Verde Islands and another line 180 degrees to the westward, or on the opposite side of the earth. Later the line was moved 270 leagues further to the west. Each party was permitted to sail in the seas belonging to the other, but neither dared trade outside his own dominions.

About 1516 a Portuguese explorer named Fernandus Magalianes was offended by King Manuel and in his indignation renounced his allegiance to that king and journeyed to the court of Castile, where he told the King of Spain that the Molucca Islands belonged to him and that he could reach them by sailing to the westward

(which would bring them within the Spanish domain according to the agreement with the Pope).

Magellan, for it was none other, set sail from Seville in August, 1519, with a squadron of five vessels. He sailed directly for Brazil and skirted the eastern coast of South America to Patagonia, where he stopped for a time. Here a mutiny arose in the crews, which Magellan ended by hanging and quartering the ringleaders. This daring navigator then assembled his fleet and on his flagship "Victory" sailed through the terrible straits, which ever since have borne his name.

The *Mare Pacificum,* or Pacific Sea, which he called the quiet water beyond, was sighted November 28, 1520. Shortly after this one of his vessels deserted and returned to Spain. Dreadful hardships were experienced during the long voyage across the Pacific, which lasted for ninety-eight days with no sight of land. The food supplies became exhausted and the water putrefied, and they supported themselves for the last part of the voyage by chewing leather which was dragged in the sea for several days to soften it, and by eating the rats which infested the ships. Magellan's fleet saw land for the first time in March, 1521. It was the group of islands about one thousand miles east of the Philippines, which Magellan named the Ladrones (meaning robbers) because the natives stole everything they could lay hands on.

Again they set sail for the Spice Islands to the west. Again land was sighted, this time a larger group, which Magellan named the Philippines, after Prince Philip, the son of his master, Charles V of Spain. Magellan was at first well received by the natives, but when he tried to convert them to Christianity by force the natives murdered him, and his fleet had to set sail without him.

Borneo was next reached, and finally in November, 1521, Tydore, one of the Clove Islands. Here the Spaniards made a treaty with the king and loaded their ships with cloves in exchange for quicksilver, cloth and glass cups. By this time, only two ships remained of the fleet of five. One of these was lost at Borneo, and the remaining vessel, the "Victory," under Sebastian del Cano, alone reached Seville, after three years of hardship, but with the achievement of having been the first vessel to circumnavigate the globe.

Other Spanish expeditions were sent to the Moluccas by the westward route and the Spaniards established trading stations of their own. The Portuguese resented this and for many years the

two nations quarrelled and fought, each maintaining that the Moluccas fell within the dominions granted it by the Pope and each had maps to prove the justice of its claims.

Expeditions were sent to the Moluccas by Spain with the west coast of Mexico as a starting point. The natives of these unfortunate islands allied themselves alternately with each nation. The strife was ended only by the sale to Portugal by Charles V in 1529 of the Spanish claim to sovereignty in the Islands. The Spaniards then devoted their attention to the Philippines, where they founded Manila and established rich commerce in products of the Orient through China. One expedition which the Spaniards sent out from Peru, discovered a group of islands so rich in gold and spices that they believed them to have been the islands from which the famous builder of the temple at Jerusalem had obtained his riches, and they were therefore named the Solomon Islands.

During nearly the whole of the sixteenth century the spice-laden carracks of the Portuguese traversing the Cape of Good Hope route made Lisbon the most important commercial centre in Europe. Her docks and warehouses were piled high with the rare and aromatic products of the Eastern countries. The distribution of these valuable commodities the Portuguese left to other nations, among which were the Venetians, now receding from their former grandeur.

The Venetians in their prosperous centuries had not been too proud to act as merchants as well as conquerors. The Portuguese were above that and left the northern European carrying trade almost entirely to the Dutch. Antwerp and Amsterdam became great international markets where "Osterling, Turk, Hindoo and Atlantic and Mediterranean traders stored their wares and negotiated their exchanges," according to Motley.

The Netherlands in the sixteenth century consisted of three divisions, i. e., the Walloons, or the provinces next to France; the Flemish, corresponding to modern Belgium, and Holland, consisting of the coastal states. It was united into what was called a States-General, whose power was subject to Spain, of which the Netherlands was virtually a tributary state.

In 1567 the Dutch revolted from the intolerable rule of Philip II and commenced the long struggle, which finally yielded them their independence. For upward of thirteen years, although a bitter military struggle was waged between Spain and the Netherlands, the commerce between the two countries went on with but slight inter-

ruption. In 1580, when Spain and Portugal became united, Philip decided to strike a final blow at the Dutch by destroying their commerce. He forbade Dutch vessels to trade in Spanish or Portuguese ports under penalty of confiscation and imprisonment of their crews. This turned the thoughts of the Hollanders to the possibility of direct intercourse with the Indies, which they had never before attempted.

During the whole of the sixteenth century the other European nations seem to have conceded to the Portuguese the exclusive title to the Cape route by right of discovery. England and Holland, while admitting Portugal's right to the Cape route and Spain's right to the route taken by Magellan, did not concede the right of the Pope to divide these rich eastern possessions between Spain and Portugal.

The rulers of England and Holland believed that if they could find a northwest or northeast passage, the opposite of the respective routes discovered by da Gama and Magellan, they would have a perfect right to trade with Cathay and the Spice Islands. Besides, the Portuguese had jealously guarded the charts of the Cape route, perfected by nearly a century of navigating research and exploration. Fortunately for Holland and unfortunately for Portugal, the Dutch had a young man named Linschoten, who, spurred by a longing for adventures in strange lands, had joined one of the Portuguese Indian fleets and had become a member of the suite of the Archbishop of Goa, where he remained for five years. In 1596, several years after his return to Holland, he published the record of his East Indian experiences.

This work was a rare storehouse of information for the Dutch, for Linschoten had recorded his observations, not only of the social, political and religious institutions of the natives and their Portuguese masters, but had written with accuracy and much detail concerning plants, animals and minerals, and of the geography, including notes on winds, currents, shoals and harbors. His work was of inestimable value to the merchant, the mariner and the scientist.

This work of Linschoten's was the greatest single factor in the subsequent triumph of the Dutch in the struggle for the possession of the trade in spices. Several unsuccessful attempts had been made in the later part of the sixteenth century by Dutch navigators to reach the Orient by a northern passage, which they believed would cut at least 10,000 miles from the distance. These efforts, of course,

were futile. They then turned their attention to the Cape route and within a year after the publication of Linschoten's book the Dutch had sent a squadron to the Eastern Archipelago.

It visited numerous native ports and was greeted everywhere by the evidences of Portuguese hatred. This expedition arrived back in Holland in 1597, with a heavy loss of men by scurvy, but at a great commercial gain, and what was more important, the initial voyage had been made. Within a few months another and larger squadron was under way, and this reached Bantam Harbor in December, 1598. This important port at the extreme western end of Java, was a great pepper market. All of the vessels were back again in Amsterdam by April, 1600, with pepper, cloves, nutmegs and mace.

In 1598 another fleet had started for the same destination by the route discovered by Magellan, and which had also by this time been traversed by Drake and Cavendish. This fleet captured two Spanish vessels en route and had a battle in Manila Harbor with another Spanish fleet. Other expeditions were sent by the Hollanders in rapid succession, and between 1595 and 1601 forty-six ships had been sent to the Orient by the Dutch, of which forty-three had safely returned.

Soon after the Dutch commenced their direct trade in the East, the merchants of Europe began to complain that spices were becoming too cheap. In 1602 the States-General granted to the Universal East India Company a charter conferring the exclusive right to trade to the eastward of the Cape of Good Hope and to sail through the Straits of Magellan. This company was given power to make treaties, levy troops and build forts. Of the prizes captured from Spain on the high seas a certain proportion was to go to the Admiralty.

The Dutch evolved a new type of vessel. Built primarily to carry merchandise and staunchly seaworthy, they could quickly be transformed into formidable fighting craft. Many of their captains were veterans of the wars with Spain. Fight after fight followed in rapid succession. Armadas were dispatched from Spain to protect the factories scattered through their new possessions, as well as to guard the richly laden carracks heaped high with stores of fragrant spices.

In 1601 a Dutch skipper, Jacob Heemskerk, while off the Malay peninsula, sighted a Portuguese carrack with a cargo of spices. Al-

though Heemskerk had but 130 men and his opponents 700, the doughty Dutchman captured the Portuguese vessel and divided the rich booty among the members of his crews. In 1602, Spilberg, the first Dutchman to trade with Ceylon for cinnamon, fought and captured three Portuguese ships and gave their captains to the King of Ceylon. Wolfert Hermann, another indomitable Hollander, with a fleet of five small vessels, engaged a Spanish armada of twenty-five vessels, captured two, sank and drove ashore a number of others and scattered the remainder.

The Dutch then settled permanently in Bantam and established their first factory within a few leagues of the spot where the city of Batavia was later located by them on a congenial swamp, which was duly laid out with canals and bridges, trim gardens and well-built houses.
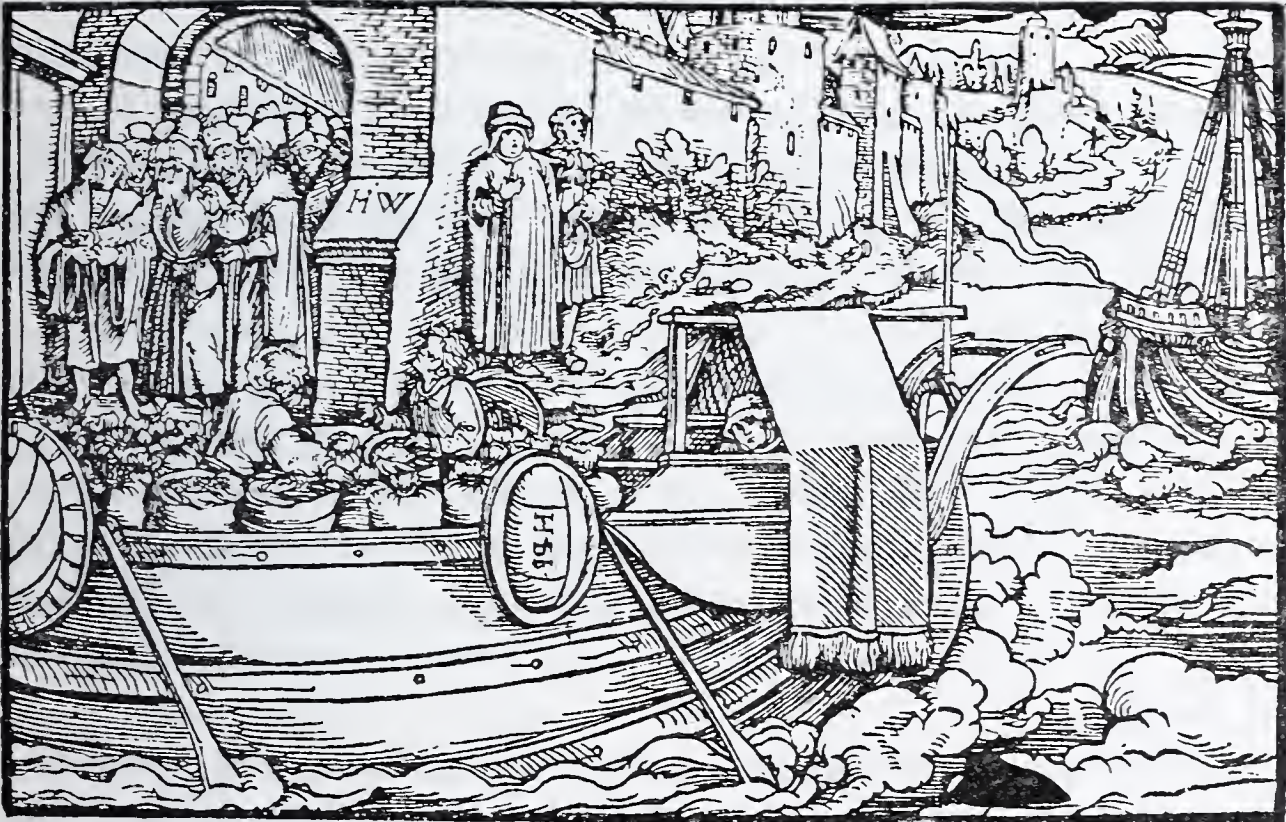
Arrival in German Port of Spice-Laden Boats.
From a Woodcut of 1539.

Many encounters between the Dutch on one hand and the Spanish and Portuguese on the other now took place. Naval battles occurred in every clime and on every sea. The Dutch, though usually inferior in numbers, both as to ships and men, were better navigators in the emergency of battle and usually won by outsailing and outmanœuvering their antagonists.

The Dutch were now not satisfied to whip their enemies upon the sea and within a few years were bombarding and capturing

Spanish and Portuguese forts all over the Eastern Archipelago. After Bantam, they established forts at Jahore, Achin and Amboyna.

The true Moluccas or Clove Islands, as previously referred to, had long been a bone of contention between the Moors, the Spaniards and the Portuguese. The Dutch now essayed to control this valuable group and the ownership shifted several times within a few years according as one or the other of the fleets was victorious. The Dutch were finally victorious under Matelieff.

Motly says of the Clove Islands: "The world had lived in former ages very comfortably without cloves. But by the beginning of the seventeenth century that odoriferous pistil had been the cause of so many pitched battles and obstinate wars, of so much vituperation, negotiation and intriguing, that the world's destiny seemed to have become dependent upon the growth of a particular gilly flower. Out of its sweetness had grown such bitterness among great nations as not torrents of blood could wash away. A commonplace condiment enough, it seems to us now, easily to be dispensed with, and not worth purchasing at a thousand human lives or so the cargo, but it was once the great prize to be struggled for by civilized nations."

The Dutch intrenched themselves in their monopoly of this spice by introducing the tree into Amboyna and similar islands under their safe control, and extirpating it from the Moluccas, its original sole habitat. As has been said, the clove tree is not found today in the Moluccas, most of the world's supply coming from Zanzibar on the East African coast, where it has been introduced during the past century.

In the case of nutmeg and mace, the continued and determined efforts of the Dutch to restrict it to the Banda Islands were long marked with success. The clove is an immature flower bud and cannot be used for propagation of the plant, but the nutmeg is a kernel or seed, and needs but to be planted in favorable climate to establish a rival source of supply. In order to prevent the nutmeg kernels from germinating the Dutch immersed them in milk of lime for several months. They later discovered that exposure to sunlight for a week would accomplish the same purpose, but so firmly established had become the custom that the practice of coating or powdering nutmegs with a white covering (liming, as it is called) still persists, at a time centuries after the original need for such pro-

cedure has passed, for the tree is now successfully cultivated in the West Indies, from which part of our supplies come at the present time.

The Dutch also established and maintained a control over cinnamon (at least the Ceylon variety) for a long time, although the continued hostility of the King of Kandy, the capital of Ceylon, necessitated the employment of thousands of armed guards during the collecting season of this valuable bark.

Batavia, under Dutch development, grew to be one of the finest cities in the Eastern world. Cosmopolitan in its population, which included Javanese, French, German, Portuguese, Chinese and Moors, besides the Dutch who ruled it, it came to be known as "The Queen of the East." This city was the centre of all activities in the Indies—political and commercial. The President was absolute in authority and held office for life. The middle of the seventeenth century was the zenith of Dutch control.

During the two centuries that have been covered by the recital of Portuguese and Dutch control, the English had not been idle in their search for a route to the Spice Islands. John Cabot, a Venetian navigator, who had offered his services to Henry VII, had essayed to reach them the year that da Gama started on his first voyage around the Cape, and had reached Labrador, this being the first expedition (except that of the Vikings) to reach American mainland. Sebastian, his son, during the following year explored the Eastern Atlantic coast of America as far south as Hatteras, always seeking an opening through which vessels might continue on their westerly journey.

Other English voyages in search of the supposed northwest passage were attempted in 1517 and 1527. In 1576 Sir Humphrey Gilbert essayed in a book to prove the existence of a northwest passage and in 1578 Richard Hakluyt wrote along similar lines. In 1589 we find that Queen Elizabeth granted authority to Adrian Gilbert to seek a new passage to China and the Isles of the Moluccas.

In 1553 an English expedition had attempted a northeast passage and found its way into the White Sea. Of the three vessels two became icebound, and were lost with all their crews, while the crew of the third, after traveling 1500 miles over ice and snow in sledges, reached the court of Ivan the Terrible, at Moscow, thus establishing the earliest commercial relations between the English

and the Russians. In 1555 the celebrated Muscovy Company was chartered, "to use all wayes and meanes possible to learn how men may pass from Russia either by land or sea to Cathia."

In 1558 an English explorer, named Jenkinson, journeyed down the Volga to the Caspian Sea and from thence reached Bokhara by caravan. He found the overland route to China closed by wars in Central Asia and reported the commerce of Bokhara as decadent. Between 1561 and 1581 six trading expeditions were sent to Bokhara over this route by the English. The trade was thus stimulated and improved and many spices were brought back to London.

Interesting information was brought back or reported by factors of the Muscovy Company during this period. One says: "There is a great river which falleth into the Caspian Sea by a town called Bachu, near unto which is a strange thing to behold, for there issueth out of the ground a marvelous quantity of oil, which oil they fetch to the uttermost bounds of Persia. It serveth all the country to burn in their houses."

In 1581 (following the accidental destruction of a Venetian galley and the abandonment of the distributing trade by them, as previously related) Elizabeth granted a charter to the "Merchants of the Levant," which essayed the same trade via the Eastern Mediterranean and Constantinople. One of the factors of this company wrote: "Without the city Cairo are to be seen divers pyramids, among which are three marvelous great. Out of them are digged daily the bodies of ancient men, not rotten but whole. And these dead bodies are the mummies which the Apothecaries do against our will make us to swallow."

Another and less creditable chapter of English activity in connection with the spice trade concerns itself with the exploits of those freebooting adventurers—Drake, Hawkins, Grenville and Oxenham, who in their little armed ships went out to harass the navies and capture the homeward bound treasure and spice ships of the King of Spain. How they sacked the cities of the Spanish Main and even sailed into the harbors of Spain itself and carried off rich prizes has been the theme of song and story for centuries.

Drake's notable voyage of circumnavigation began in 1577. Like his illustrious predecessor, Magellan, he was confronted with a mutinous condition and was compelled to execute his warm friend, Captain Doughty, who had been second in command, for trying to desert with one of his vessels. It was upon this voyage that Drake

discovered Cape Horn, after having passed through Magellan's Straits, by being beaten back by a storm. Drake's fleet spread havoc among the Spanish settlements on the Pacific coast of South America. He later visited the Philippines, the Moluccas, Java and Sumatra, and finally rounded the Cape of Good Hope, and arrived home in 1580.

Philip of Spain demanded of Elizabeth that Drake be publicly hanged as a pirate for his attacks upon the Spanish settlements and ships. Elizabeth's canny answer was: "If we find Drake has injured our friends he will be duly punished."
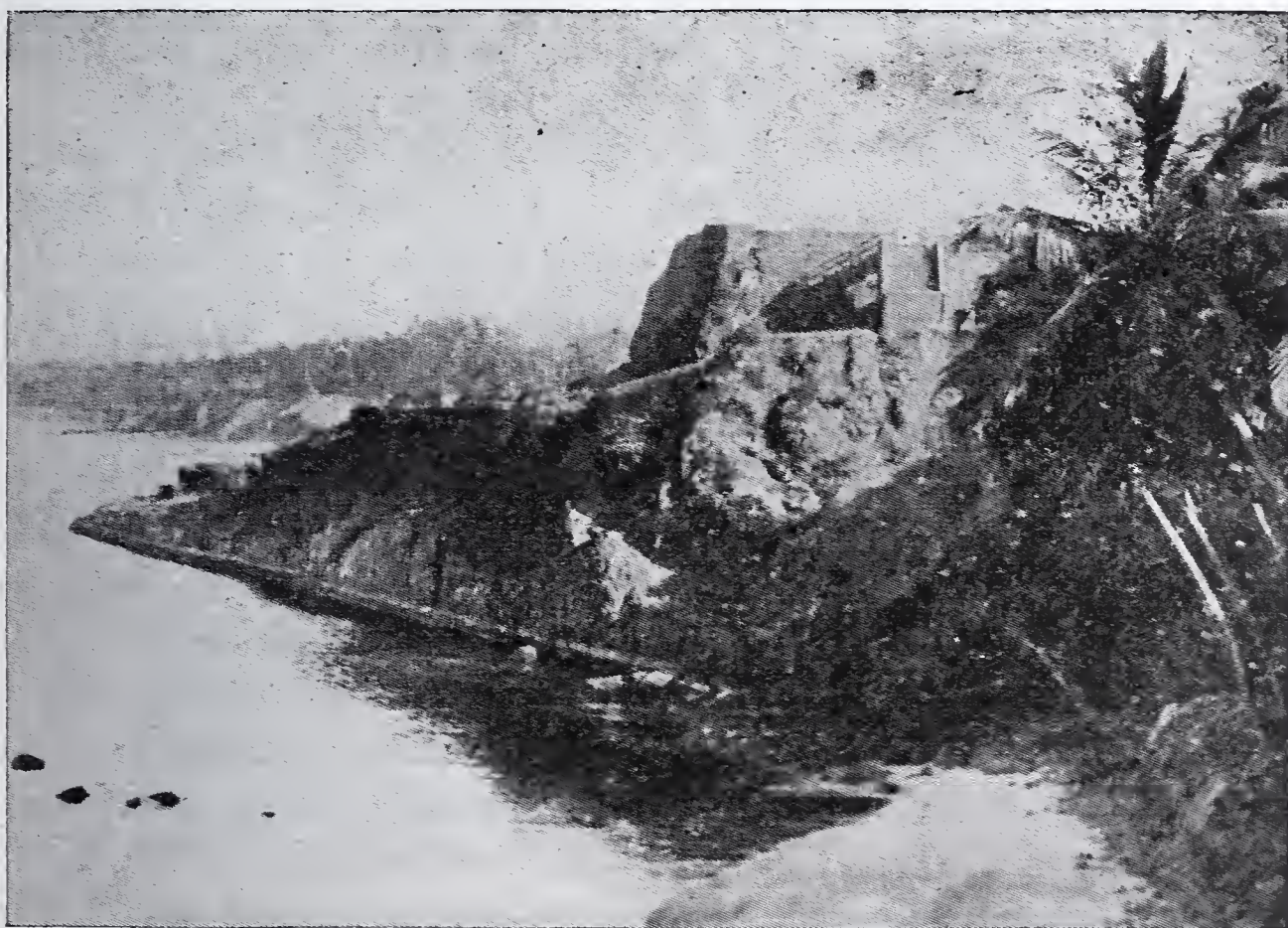
Ruins of Portuguese Fort on Telicherry Coast, India.

Thomas Candish, an English captain, in 1586 circumnavigated the globe by the same route and came back laden with the choicest treasures of nineteen Spanish ships, which he had pillaged, burnt and sunk. He brought to Europe the first star anise that had been seen in the West. The English activities did not gain them much, but the authority of the Pope's bull had been nullified and thenceforth the trade in the East was open to him who could reach and hold it.

Although several of the English voyages had been successfully accomplished before the Dutch began, the Hollanders soon left the

English behind in the strenuous race for the trade of the Indies.
This led the English merchants to protest to their sovereign. In
consequence of these protests, Elizabeth, in 1599, signed the charter
of "The Governor and Company of Merchants trading to the East
Indies." This conferred the privilege of exclusive trade into the
"countries and ports, towns and places of Asia, Africa and America
or any of them beyond the Cape of Buena Esperanza or the Straits
of Magellan, where any traffic may be used."

The first expedition under the new company sailed February
13, 1601. After capturing a Portuguese carrack on the way down
the African coast, and after many hardships due to scurvy, the
English fleet reached Achin, Sumatra, in June, 1602, and found
Spanish, Portuguese and Dutch ships, besides native traders.

Captain James Lancaster, in charge of the expedition, presented
a letter from Elizabeth to the ruler, and also numerous gifts attrac-
tive to the native prince. A treaty was granted, but Lancaster soon
found that getting a treaty was considerably easier than getting a
cargo, so he went out on the high seas and captured several Portu-
guese carracks. Elizabeth died before Lancaster's return in 1603.

The English trading policy was entirely different from any of
their competitors. They made their foreign trade build up their
home industries by sending products of their manufacture to barter
for spices, etc. At this time every English merchant vessel was a
privateer. They had learned from Lancaster's experience that it
was easier to capture Portuguese carracks than to trade with the
natives, so an era of brigandage and freebootery began, which con-
tinued until the Portuguese were entirely crowded out by the Dutch
and the English, who were always the aggressors and also better
sailors and fighters.

The last blow to Portuguese commerce occurred when the
English, after a long siege, captured the port of Ormuz, which was
the key to the commerce through the Persian Gulf. The English
and the Dutch then started bickering and fighting and their disagree-
ments were not ended until after the Napoleonic Wars, the final
settlement being the Anglo-Dutch Treaty of 1824, although as late
as 1871 and again in 1895, supplementary agreements were re-
corded.

Before closing, let us give some slight consideration to the spices
themselves, enumerating them and referring to particular points of
interest in their individual histories. Spices may be defined as "sub-

stances aromatic or pungent to the taste, or to both taste and smell."
In Circular 136 of the U. S. Department of Agriculture, in which
standards for many food products are provided, spices are defined
as "Aromatic vegetable substances used for the seasoning of food."
The list given in this circular is a very complete one and is as fol-
lows:

Allspice, aniseed, bay leaves, capers, caraway, cardamom, cap-
sicum (Cayenne or red pepper), celery seed, cinnamon, cloves, cori-
ander, cumin, curcuma (turmeric), dill, fennel, ginger, horseradish,
mace, margoram, mustard (white and black), nutmeg, paprika, Par-
adise grains, parsley, pepper (black, white and long), saffron, sage,
savory, star aniseed, tarragon and thyme.

Of these more than thirty kinds of spices, to which garlic,
onions, leeks, chervil and others might also be added with pro-
priety, only a few are mentioned in the Bible. They are anise, cin-
namon, coriander, cumin, dill, hyssop, mustard and saffron.

The older authors divided spices into three well defined groups,
i. e., stimulating, as mustard, capsicum, horseradish, etc.; aromatic,
as cinnamon, cloves, nutmeg, etc.; and sweet herbs, as thyme, sage,
marjoram, savory, etc.

The retail merchandising of spices was at one time exclusively
the province of the apothecary; later the apothecaries became asso-
ciated with the spicers or sellers of spices and foodstuffs, and those
who handled in wholesale quantities were known as grocers, because
they sold in gross or large lots, a term which in our time has come
to be used for one who sells foodstuffs of various kinds, including
spices.

In the sixteenth and seventeenth centuries spices had become
much reduced in price, but they were still so expensive that the
laborers in the warehouses and docks were provided with special
canvas suits without pockets. In our own time they have become
so commonplace and cheap that every household has a spice cabinet
or closet, or a collection of about a dozen of those which are more
frequently used.

Allspice, which is called by that name because its flavor re-
sembles a blending of several spices, is a product of the Western
hemisphere, a native of Jamaica, from whence comes most of the
world's supply. Taken back to Europe on one of Columbus's voyages
the Spanish gave it the name Pimienta, which means pepper, because

of its resemblance to the black peppercorns. This was later changed to Pimento, which is its pharmacopœial name.

Aniseed originally came from western Mediterranean countries, particularly Crete and Egypt. It is now grown in many European countries, and before the World War much of the best anise came from Russia.

The *bay leaves* used for condimental purposes are the product of a laurel species, entirely different from the plant which yields the leaves used in making bay rum. Bay leaves come from Spain and Italy. The sticks of licorice extract, so attractive in our childhood days, were packed with bay leaves to keep them from being broken in transit. The bay leaves were also used in making the wreaths with which the victors in the ancient games were crowned.

Capers are the flower buds of a shrubby plant and are brought from southern European countries.

Caraway seeds, popularly known as "kümmel" when used in rye bread, were originally grown in Europe, which still furnishes much of the commercial supply, although this is one of the few spices now used in the Orient although not its original home.

Cardamom has been used in India from the remotest times. It has always figured more prominently as a drug than as a spice in Eastern countries. Ceylon and India furnish most of the world's supply.

Capsicum species (red or Cayenne peppers) are natives of the Western hemisphere. They were cultivated from time immemorial in Mexico and South America, and are not now known in the wild state at all. Columbus sought for black pepper and found red. The many varieties of red pepper now cultivated in various parts of the world have been of great importance and interest. Little or none of the world supply (not even our own) comes from America. Mombassa, on the west coast of Africa (that from Cayenne is esteemed as the finest), and Japan, are rivals for the world's markets of this superpungent spice, which has enriched (?) our language with the slang word "pep." There are less pungent or even sweet varieties of capsicum, popularly known as paprika. The best of these come from Hungary and Spain. The word "Chilli," used in Chilli sauce, chilli-con-carne-, etc., is of Mexican origin and was being used by the followers of Montezuma when Cortez arrived.

Celery seed is a native of Europe. It is mentioned in the Odyssey and by Dioscorides. The plant is cultivated here largely as a vegetable but our supplies of the seed come from Europe.

Cinnamon has been mentioned as a native of Ceylon, which is in all probability its original habitat. It has been held in high esteem from the most remote period. It was one of the first spices sought in all Oriental voyages. Other varieties come from China, Saigon and Batavia. Until the eighteenth century none was cultivated. The well-known hymn

"What though the spicy breezes
Blow soft o'er Ceylon's isle,
Where every prospect pleases
And only man is vile,"

was probably inspired by thoughts of the Portuguese and Dutch cruelties.

The *clove* tree, as has been said, is no longer found, even in a wild state, in the true Moluccas. The East Indian supplies came through the Dutch at Amboyna and the English at Penang. In the seventeenth century the clove tree was planted at Zanzibar, off the East coast of Africa. From this point much of the present supply comes. The methods of the Dutch traders, practiced to keep up the prices of this spice, were shown about a half century ago, when a cyclonic disturbance in Zanzibar uprooted and destroyed nearly all the mature fruit-bearing trees. It was years before the Zanzibar plantations again became productive and the Dutch supplied the extra needs from surplus stocks held at Amboyna. The marks on some of these Dutch packages, when they arrived in New York, showed that they had been held in stock for nearly 100 years by the Dutch, and they were still in excellent condition. The preservative effect of cloves and of clove oil is well known. Amboyna, Penang and Zanzibar furnish the world's present supply.

Cloves were the most highly esteemed and the most valuable of all the spices, even at very remote periods. During one of the Chinese dynasties of the third century B. C. it was customary for officers of the court to hold a clove in the mouth before addressing the sovereign, in order that the breath might have an agreeable odor. This custom was also prevalent in the dynasties of a much later period, even in that preceding the Volstead era, but for a somewhat different purpose.

Coriander is a native of Greece and Egypt. It is cultivated in various parts of continental Europe and has been introduced into Africa and India.

Cumin was well known to the ancients. It is referred to in both the Old and the New Testaments. It was one of the most commonly used spices in the Middle Ages, but is little used at present except in blends and mixtures. It comes into commerce from Sicily, Morocco and India.

Curcuma or Turmeric (tumeric, as it is usually called or spelled by the careless or illiterate) is a native of India where it is highly esteemed both as a condiment and a dyestuff. It is the predominating ingredient in curry powder. Curry is the Oriental name for a dressing, relish or flavoring for boiled rice and it is used both as a noun and as a verb. The entire supply comes from India.

Dill is another spice known to the ancients and referred to in the Bible. Its principal use now is to impart a flavor to a certain type of pickled cucumber. It is usually grown locally in whatever part of the world it is used.

Fennel seed is a near relative of anise, caraway, coriander, cumin and dill. It is a European plant, known to the ancient Romans. It is cultivated in France, Germany, Austria and Italy, and also in India and China, where it has been introduced. Our supplies come from Europe. It is used more in medicine than as a spice.

The *Ginger* plant is a native of India, from which it has been introduced into China, the East Indies, Africa and the West Indies (Jamaica). Some varieties of ginger are peeled, scraped and "limed," probably in the earlier days to prevent propagation by planting. Its pungency and pleasant aroma make it popular in confections and beverages, and its stimulating properties are recognized, not only in medicine, but in present day slang, as every one knows what is meant when the request is made to "put some ginger into it." The principal commercial supplies reach us from Africa and Jamaica, although Cochin and Bengal gingers are also known.

Mace and *Nutmeg* are different parts of the same fruit. The tree is a bushy evergreen, found wild in a number of islands adjacent to the western peninsula of New Guinea, including the Moluccas, and in the Bandas, a group of volcanic islands which played an important part in the romance and history of the spice trade. It has been introduced and cultivated in Sumatra, Malacca, Bengal, Singapore and Penang, as well as in Brazil and the West Indies in our own hemisphere. Its use had been known throughout Europe even prior to the Venetian control of the spice trade. Strangely enough,

although valued highly in all other parts of the world as a condiment or flavor, neither nutmeg nor mace is ever so used in the islands where the plant is indigenous.

The fruit is the size of a small peach, having a thick, fleshy pulp, which encloses the kernel (the nutmeg), surrounded by the membranous mantle, which is the mace. America's supply comes from both the East and the West Indies. Siau mace and nutmegs come from the Dutch Islands north of Celebes. Penang varieties come from English possessions. The West Indian supply comes principally from New Granada.

Several times during the early days of Dutch control it is reported that heaps of nutmegs as large as a church were burned by the Hollanders in order to keep up prices.

Some kinds of nutmegs or mace, such as the Bombay variety, are of so little spice value that they are looked upon as adulterants. It will be remembered that Connecticut is jocularly known as the "Nutmeg State," from the reputation given it by the keen Yankees, who are alleged to have made and sold wooden nutmegs (but once to the same customer).

Marjoram is a fragrant herb used in soups, sausages, etc. The supply comes principally from France.

Mustard is one of the most widely distributed and ancient of plants. Its earlier uses seem to have been more medicinal than dietetic. It is extensively cultivated in Europe, from which country our supplies come. The two varieties, white and black, also commonly called yellow and brown, or English and German, when prepared, are distinctly different in composition and flavor.

Paradise Grains are an extremely pungent seed, very small and very hard. Under the name of Melegueta Pepper and Guinea Grains it was used for centuries in Europe as a stimulating condiment. It still comes from its original habitat along the Gold Coast of Western Africa.

Pepper, black and white, is the fruit of a tropical vine. It was one of the earliest used and most highly esteemed of spices and for centuries was the staple article of trade between Europe and India. It was the medium of exchange when money was scarce in some periods in Europe. At one time it was heavily taxed, the figure reaching over $1 a pound in England during the seventeenth century.

The black pepper is the immature or unripe berry, the white pepper is the same fruit allowed to mature on the vine. During this process of maturing its color changes and a different flavor develops which is attractive to some and disagreeable to other persons.

Some commercial varieties of white pepper are made by decorticating the commercial black pepper and then grinding the lighter colored inner portions of the fruit. This is expensive, but is esteemed very highly for use when the black specks of the ordinary black pepper would be objectionable.

Long pepper is a different fruit altogether, although coming from the same genus of plants. It is inferior in flavor and only found rarely in commerce and then as an adulterant at times. The world's supply of pepper comes from Malabar, Sumatra and Singapore.

Sage, savory and *thyme* are aromatic herbs used in cooking and seasoning meats particularly. They are all cultivated in Europe and our supplies come from that country. The fresh herbs, sold as "pot herbs" are grown in this country, usually by the farmers themselves, who bring them to market tied up in little bunches.

Star Anise is an anise-flavored curious fruit from China, rarely used as a spice, but frequently as a source of the volatile oil of anise.

Tarragon is an herb used principally for giving a characteristic flavor to vinegar. It comes from Europe.

And here we bring to a close our story of spices—a story which has reached back through days of daring and adventure when it meant something to have a "ship come home"; a story which has in it more of intrigue and treachery than of altruism or Christian spirit; a story which brings vividly to our minds pictures of Poseidon's Seven Seas, of monsoon-whipped tropical jungles, of "elephants a pilin' teak," of lines of spice laden camels with "their silly necks a bobbin' like a basket full of snakes."

Here is material for bard, historian, novelist, sculptor, painter or musician. Each decade furnishes inspiration for an epic, each century details for a ponderous tome of interest and fascination rarely equaled. The high lights only have been shown. In the shadows lies material for the future, and the seeker has reward enough in the search whether he has hearers or whether he has not. Selah!

CATALYSIS AND CATALYSTS.

By Samuel P. Sadtler, Ph. M., Ph. D.

(Emeritus Professor of Chemistry, Philadelphia College of Pharmacy and Science.)

A number of isolated observations, in which the presence of an activating substance, not figuring apparently in the reaction when expressed in its simplest terms, had been recorded in the early part of the nineteenth century. Thus the conversion of starch to sugar by means of dilute acids had been recorded by Kirchhof in 1812; the action of finely divided platinum to oxidize ethyl alcohol to acetic acid was demonstrated by Edmond Davy in 1820; Döbereiner's use of spongy platinum to inflame a jet of hydrogen gas in the presence of oxygen or air noted in 1822; and lastly the part played by sulphuric acid in the conversion of alcohol into ether noted by Mitscherlich in 1834, were all on record when Berzelius in a communication in 1835 called attention to certain features distinguishing these reactions. He says: "It is then proved that several simple and compound bodies, soluble and insoluble, have the property of exercising on other bodies an action very different from chemical affinity. By means of this action they produce, in these bodies, decompositions of their elements and different recombinations of these same elements to which they themselves remain indifferent.

"This new force, which was hitherto unknown, is common to organic and inorganic nature. I do not believe that it is a force quite independent of the electro-chemical affinities of matter; I believe, on the contrary, that it is only a new manifestation of the same; but, since we cannot see their connection and mutual dependence, it will be more convenient to designate the force by a separate name. I will, therefore, call this force the *catalytic force,* and I will call *catalysis* the decomposition of bodies by this force in the same way that one calls by the name *analysis* the decomposition of bodies by chemical affinity."

Clearly Berzelius, while making a distinction in name, was unable to indicate the nature of the difference in the several reactions.

Nor was the matter improved by Liebig, who discussed catalytic reactions shortly after this. The introduction of the idea of "chemical reaction velocity," as the key to the meaning of catalytic

reactions, first by Wilhelmy and later elaborated by Ostwald, was the important step in advance. Ostwald therefore defines a catalyst as follows: "Catalysts are substances which change the velocity of a given chemical reaction without modification of the energy factors of the reaction." Later writers have widened this view of Ostwald by insisting that a catalyst may actually initiate a reaction. So the broadest definition is that given by Sabatier, one of the most fruitful workers in this field. He says: "By catalysis we designate the mechanism by virtue of which certain chemical reactions are caused or accelerated by substances which do not appear to take any part in the reactions." It must be noted about this definition, however, that, while the catalyst does not figure in the reaction which sums up the ultimate change effect, we learn nothing from it as to how the catalyst acts on the substances with which it is brought in contact.

"The theories which have been advanced to explain the mechanism of catalysis fall into two classes, the chemical and the physical. The former asserts that the effect of the catalyst is to be attributed to the continuous formation and decomposition of unstable intermediate products; whilst the physical theory explains the phenomena as being due to the condensation, or increase in concentration, of the reacting substances at the surface of the catalyst, such increase in concentration being brought about by capillary forces."

Many of our commonest reactions like the well-known liberation of oxygen from a mixture of potassium chlorate and manganese dioxide and its liberation from bleaching powder in the presence of a cobalt catalyst, undoubtedly depend on the formation of unstable intermediate compounds. Indeed the effect of finely divided metals as catalysts may also depend upon the temporary formation of metallic hydrides easily decomposable. So the chemical theory seems to have an excellent basis, but there are also cases where so far no intermediate compound can be figured and the physical theory seems the best explanation. For convenience, two general divisions have been made in the discussion of catalytic reactions; catalysis in homogeneous systems and catalysis in heterogeneous systems.

The first class, that in homogeneous systems includes cases where the catalyst is dissolved in or intimately mixed with at least one of the reacting constituents. All cases of soluble ferments figure therefore as illustrations of homogeneous catalytic reactions. The

action of dilute acids as in the inversion of starch or sugar is similarly an illustration. The action of water vapor in inducing reaction of certain gaseous mixtures is also an illustration.

There are many cases of chlorination, oxidation or reduction, where intermediate chemical compounds are indicated as formed, which belong to this class.

The second class, that in heterogeneous systems, covers the cases where a solid catalyst preferably in finely divided condition is brought into contact with gaseous or liquid systems or mixtures. This includes many of the great industrial processes like the contact sulphuric acid process and the hardening of oils or fats by hydrogenation in the presence of finely divided nickel.

Before proceeding with the special mention of catalytic reactions illustrating this classification, we will note some special conditions applying at times to many cases of catalysis.

AUTO-CATALYSIS is a term used by Ostwald to characterize those cases in which the product of the reactions accelerates the reactions. Thus pure nitric acid acts only slowly on many pure metals, silver, copper, bismuth, cadmium and mercury, but when once it is started, the reaction accelerates itself because nitrous fumes are produced which facilitate the attack so that the reaction may become violent.

Similarly, water produced in the reaction frequently greatly accelerates the catalytic reaction of gaseous mixtures. Again, in the hydrolysis of esters by water in the presence of acids, the hydrolysis once started yields the acid which greatly accelerates the reaction.

ACTIVATORS. In many catalytic reactions it has been found that the addition of small quantities of "promoters" or "activators," as they are called, has the result of increasing the activity of catalysts in a very remarkable manner. This appears to be specially the case where the catalyst is a metal, and then the promoters may be other metals, or oxides, hydroxides, or salts of the alkali metals, of the alkaline-earth metals, and generally of those metals which yield oxides and salts which are not reducible by hydrogen; various other instances of the advantageous employment of promoters are given in the description of the synthesis of ammonia, of the oxida-

tion of ammonia to nitric acid, and of other catalytic processes. The
mode of action of promoters is not understood; indeed, our knowl-
edge of the phenomenon is at present limited to some isolated facts,
but there can be no doubt that further experimental investigations
will lead to a more extended application of this method of activating
catalysts.

NEGATIVE CATALYSERS (including stabilizers and catalyser pois-
ons). There are on record many cases in which the addition of cer-
tain substances has an inhibiting effect on the progress of the reac-
tion. We would note first the case in which the change is simply
retarded. Substances having such effect are known as *stabilizers*.
Thus the presence of a trace of sulphuric or hydrochloric acid with
hydrogen peroxide retards very greatly the rapidity with which it
decomposes; the addition of a small amount of alcohol inhibits the
decomposition which chloroform undergoes in the presence of light
and air; hydrocyanic acid is stabilized by traces of hydrochloric or
sulphuric acid. To the pharmacist, the importance of stabilizers in
some of the U. S. P. preparatons is so well known that a mere men-
tion is sufficient. Much more active as inhibiting or neutralizing
agents are what are known as *catalyst poisons*. Traces of these sub-
stances will completely stop the action of the most active catalysts,
which therefore in practice have to be guarded against their con-
taminating influence, which in common language poisons or renders
completely valueless an otherwise active and valuable catalytic agent.

"It is frequently observed that catalytic agents lose their ef-
ficiency after being in use for some time, and as a rule this is due
to the presence of substances which have an injurious influence. In
the contact process for the manufacture of sulphuric acid even
traces of arsenic compounds in the gases soon render the platinum
catalyst quite inactive; in the synthesis of ammonia from its ele-
ments, iron containing as little as 0.01 per cent. of sulphur is of
very little use as a catalyst; when using finely divided nickel as a
catalytic agent Sabatier found that traces of bromine in the air of
the laboratory rendered it impossible to hydrogenate phenol which
had stood there overnight in an open flask, and that benzene which
had not been scrupulously freed from thiophen could not be con-
verted into cyclohexane."

"It will be observed that even minute traces of poisons may have disastrous effects, and therefore, for certain classes of reactions, it is essential to provide for the preparation of contact masses free from poisons or for the removal of such poisons from them, and also for the careful purification of the reacting substances."

VELOCITY OF CATALYSIS REACTIONS. As the most distinctive feature of the action of a catalyst is the acceleration of a reaction under its influence, the question of velocity and how influenced becomes important, and there are three of these influences to specially note. Temperature plays an important role. Many catalytic reactions do not take place except above a certain temperature and it greatly increases the velocity of the reactions once started. In many cases there is an optimum temperature ranging within relatively narrow limits, and above this range the nature of the reaction (especially with organic compounds) may change radically or it may cease to be effective. Increase of pressure, the second influence, is only of importance in gaseous systems or in systems having a gaseous phase. For instance, the hydrogenation of liquid fats by gaseous hydrogen is in many cases facilitated by the use of pressure. On the other hand, the decomposition of some organic compounds such as alcohols in the presence of hydrogen is facilitated by reducing the pressure. The quantity of the catalysts is a third influencing element.

"In homogeneous systems, in which the catalyst remains in intimate mixture with the components of the reaction, it acts by its mass and its action increases with its concentration.

"In the manufacture of sulphuric acid by the lead chamber process, in which oxides of nitrogen serve as the catalyst, the velocity is proportional to their concentration up to a certain limit.

"In the inversion of sugar solutions by mineral acids and in the saponification of esters by the same agents, the active agents in the catalysis are the free hydrogen ions arising from the electrolytic dissociation of the acids and the velocity of the reaction is proportional to the concentration of these ions.

"In the catalytic decomposition of hydrogen peroxide by small amounts of alkali, the rapidity of the decomposition is nearly proportional to the concentration of these ions."

In heterogeneous systems, the catalyst may be for instance a solid immersed in a liquid or gaseous medium and exerts its useful

purpose only on its surface. Hence, the action depends largely upon the extent of the surface. The state of division of a solid catalyst is a matter of prime importance. With a solid in a fine powder which is readily penetrated by the gas, the useful surface is extremely large as compared with the exterior surface of the layer. Some metals, like nickel in sheets or tin foil, have practically no catalytic power, but in finely divided nickel, it is highly developed and of the greatest importance.

The number of substances capable of acting as catalysts is already very large and continues to increase with the fuller study of various chemical reactions. We find this catalytic action developed by the most varied materials; elements, oxides, mineral acids, bases, metallic chlorides, bromides, iodides, fluorides and oxygen salts, ammonia and its derivatives, and various organic compounds. Some distinguishing differences may be noted. Non-metallic elements are generally effective because of the way in which they can form unstable intermediate compounds which themselves act as facilitating catalytic change. On the other hand, the metals preferably act by surface action, either as finely-divided solids or when in so-called colloidal solution. These latter are at times extraordinarily active as catalysts but require the presence of protective colloids in solution with them to enable them to hold their activity.

Among organic compounds, we have an interesting class occurring in vegetable or animal life products known as *Enzymes*. These are catalysts produced by living organisms, and in all probability are substances of definite chemical composition. In many respects their action resembles that of inorganic catalysts, and especially of such metals as platinum when in the colloidal state. They are specific in their action; that is to say, a certain definite enzyme is required to bring about a particular transformation.

As in the case of inorganic catalysts, a very small quantity of an enzyme will transform a relatively large amount of the substance undergoing change, and in general the velocity of the reaction is proportional to the quantity of the catalyst present, whilst the final result is independent of that quantity. Enzymes, also, like many inorganic catalysts, are very sensitive to the action of "poisons," such as hydrocyanic acid, sulphuretted hydrogen, mercuric chloride, etc.; moreover, in many cases their activity is enhanced by the presence of small quantities of promoters. For instance, the efficiency of lipase

in hydrolysing fats is increased by the addition of a trace of manganous sulphate, and trypsin, which is practically inert in acid or neutral solution, is greatly assisted in its action by the presence of alkalis. Auto-catalysis, positive or negative, plays a considerable part in the changes of activity of an enzyme during the course of its action.

"There are, however, certain differences between enzymes and inorganic catalysts, some of which undoubtedly arise from the character of the former as organic colloids. Enzymes are sensitive to heat. In catalysis with these substances, rise of temperature up to a certain point increases the rate of change, and for each enzyme there is a particular optimum temperature, frequently in the neighborhood of 40°, at which its activity is a maximum. At higher temperatures, from 60° to 100°, they are as a rule gradually destroyed, but some under certain conditions are able to withstand the temperature of boiling water. Moreover, although enzymes resemble ordinary catalytic agents in being active in very small concentrations, they lose their activity when a certain amount of the substance on which they act has been transformed; this amount may be large, but is not, as in the case of inorganic catalysts, practically without limit. In many cases the enzyme itself disappears in the course of the reaction."

SOLVENTS. If we take the broad definition of a catalyst either as stated by Sabatier already quoted or the very similar one of Ostwald, we must include solvents as figuring in many reactions as catalysts. Thus dry chemical substances can be mixed intimately in powdered form without any chemical change resulting, but the addition of water which establishes perfect contact between the two substances immediately starts the reaction. The water may be recovered completely unchanged by the reaction. It has acted only as a catalyst. Other solvents may act in a similar way. Solvents are not commonly classed with true catalysts however, as the term is usually reserved for such substances as act in small concentration and yet are able to cause large quantities of other substances to react.

We will now briefly note some of the most important industrial applications of catalytic reactions which will give an idea of the scope of this method of chemical change.

Inorganic Catalytic Reactions and Processes.

The "chamber process" for the manufacture of sulphuric acid is one of the oldest of our great technical processes. It depends upon the oxidation of sulphurous acid or sulphur dioxide with atmospheric oxygen through the catalytic agency of oxides of nitrogen. It is true that the exact reactions involved in the several stages of this process are not so clear that general agreement upon them has been reached, but that the oxides of nitrogen serve as oxygen carriers is clearly recognized. The absorption of these oxides of nitrogen in the Gay Lussac tower and their return to the beginning of the cycle of reaction in the Glover tower shows the recognition of their function. The newer or "contact process" of sulphuric acid manufacture is an illustration of another method of catalytic action, as here sulphur dioxide and oxygen are caused to form sulphuric anhydride by the catalytic action of finely divided platinum. That highly diluted sulphur dioxide such as found in the mixture of gases from pyrites burners could react in the presence of an active catalyst like platinized asbestos was clearly shown about 1898 and after that the success of the process was definitely settled, although many engineering difficulties had to be overcome. The chamber process operates more satisfactorily when monohydrate acid is desired, while the contact process is more suitable for the production of "oleum," or sulphuric acid containing dissolved SO_3.

The production of chlorine may be accomplished by the oxidation of hydrochloric acid in several ways, but in each case the reaction is a catalytic one. For the direct use of oxygen as a reagent to act upon hydrochloric acid gas a catalyst is necessary and in the Deacon process we have heated cuprous chloride used as such. The first action is supposed to be the formation of an oxychloride of copper which reacts with the hydrochloric acid gas to form cupric chloride, which is then decomposed by heat regenerating cuprous chloride and liberating chlorine.

The cuprous chloride catalyst is deposited upon broken clay bricks or upon pumice stone. Various other catalysts have been proposed as substitutes for the cuprous chloride, but it seems to be the most efficient in practice.

Weldon's process for the oxidation of hydrochloric acid in solution depends first upon the action of manganese dioxide as oxidizer whereby chlorine is liberated and manganous chloride is formed and

then upon the effect of aeration at 50° to 60° C. upon the manganous chloride solution made alkaline by the addition of lime. The result is the precipitation of "Weldon mud," $CaO.2MnO_2$. This is then used under the name of "regenerated manganese dioxide" along with hydrochloric acid in the first stage of the process.

The greatly increased demand for hydrogen gas for industrial uses has led to the development of a number of catalytic processes for its production, some of which are in successful use. Thus in the presence of catalysts, steam and carbon monoxide (or water-gas containing carbon monoxide and hydrogen) react as follows:

$$H_2O + CO = H_2 + CO_2.$$
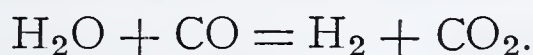
Oxides of the iron group are largely used as catalysts. Or lime may be used when the CO_2 produced is absorbed and a purer hydrogen remains. The liberation of hydrogen from liquid water acting upon iron at high heat under pressure is very notably improved by the presence of a small amount of ferrous chloride as a catalyst.

The synthesis of ammonia from the elements hydrogen and nitrogen under pressure in the presence of a catalyst, as accomplished by the Haber process, is one of the great industrial achievements of today. It was developed in Germany just before the outbreak of the war and the production in terms of sulphate of ammonia grew from about 20,000 tons in 1913 to about 500,000 tons in 1917. The process operates at temperatures between 500° and 600° C. and at high pressures. A great variety of catalysts have been used such as uranium, molybdenum and tungsten nitrides, but iron in a fine state of subdivision and made active by a small amount of a promotor is now used. The catalyst is easily poisoned by a trace of sulphur.

The process has also been independently tried and somewhat simplified by the General Chemical Company in this country.

The oxidation of ammonia in the presence of a simple catalyst may also be effected for the production of nitric acid, through the intervention of the oxides of nitrogen first produced, which react with water to form nitric acid. This was developed by Ostwald with the aid of a platinum catalyst, but iron with bismuth as a promotor has been found very effective.

A number of other promoters have been also used, but the

important feature is to remove the oxides of nitrogen from the heated catalyst as quickly as possible, as they suffer decomposition very quickly at the temperature of their production.

The recovery of sulphur from alkali waste (CaS) by the Chance process also involves a catalytic process. The treatment of the alkali waste with carbon dioxide gas liberates a mixture of gases containing about 25 per cent. of hydrogen sulphide. This is decomposed with partial oxidation by passage with a current of air over heated oxide of iron as a catalyst at about 200° C. Water is formed and sulphur separates out and is carried along with the water vapor and condensed.

The removal of CS_2 impurity from coal gas by a catalytic reaction using metallic nickel as catalyst may be mentioned in passing as another valuable industrial application of catalytic methods.

ARTIFICIAL GRAPHITE. "The production of graphite from coke or anthracite on the manufacturing scale was successfully worked out by Acheson, to whom the possibility of the process was suggested by his previous work on carborundum (CSi). When a mixture of sand and coke is heated to a high temperature in an electric furnace, the carborundum produced is found to be surrounded by a certain quantity of graphite. Investigation showed that this graphite had been produced by decomposition of some of the carborundum, and that the conversion of amorphous carbon into graphite does not require the presence of sufficient silica to combine with all the carbon, but that a far smaller quantity is effective. Moreover, other oxides than silica, for example, ferric oxide, aluminum oxide, and boric oxide, are also active to varying degrees in bringing about the transformation.

"The action of these oxides is undoubtedly catalytic, and the most probable explanation of their mode of action is to be found in the assumption that carbides are formed as intermediate products. When, at the high temperature of the furnace, the oxide has been reduced by the carbon the liberated metal forms a carbide, which subsequently decomposes, giving graphite. The metal then combines with more of the amorphous carbon, and the process continues until all the carbon present has been converted into graphite, when the metal volatilizes away. This explanation is supported by the fact that after all the amorphous carbon has been converted into graphite

the charge can be almost completely freed from impurities by further heating.

"In making the finest qualities of lubricating graphite the raw material used is petroleum coke, which is mixed with 1 to 2 per cent. of ferric oxide as catalyst. Lower qualities are made from anthracite ground to small particles; in this case the silica, alumina, and ferric oxide naturally present in the anthracite are sufficient in quantity to catalyse the reaction."

CARBON TETRACHLORIDE. "At the ordinary temperature chlorine has little or no action on carbon disulphide, but if the latter contains a catalyst, or 'chlorine carrier,' such as iodine, antimony pentachloride, etc., a rapid reaction occurs which results in the formation of carbon tetrachloride and sulphur monochloride:

$$CS_2 + 3Cl_2 = CCl_4 + S_2Cl_2.$$
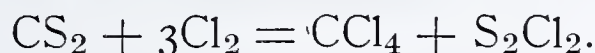
"The sulphur monochloride produced in this reaction can be caused to react with carbon disulphide in presence of a catalyst with formation of carbon tetrachloride and sulphur:

$$CS_2 + 2S_2Cl_2 = CCl_4 + 6S.$$
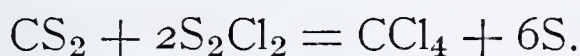
"The catalyst employed is a metal or metallic halide, preferably iron or ferric chloride. Excess of the chloride of sulphur is used, because then the reaction is rendered less violent and the yield is improved. The mixture of carbon disulphide and sulphur monochloride, with addition of the catalyst, is heated to about 60°, at which temperature the reaction begins, and when it is completed the liquid is heated to boiling for a short time. On cooling the sulphur separates in crystals; the liquid is fractionally distilled in order to separate the carbon tetrachloride from the excess of chloride of sulphur, and the crude tetrachloride is purified."

CYANIDE FORMATION. The fixation of atmospheric nitrogen in the form of a metallic cyanide is another important achievement based upon catalytic reactions. The recent work of Buchner can be noted as one of the best known processes for this end. Mixtures of alkaline carbonates and carbon with iron as catalyst are moulded into briquettes and heated in a current of nitrogen at a temperature of from 800° to 900° C. The process while successful on a small scale has met with many engineering difficulties and is not yet carried out on a continuous manufacturing scale.

Organic Catalytic Reactions Processes.

We made reference in the beginning of this account of catalysis to the early observations of the power of finely divided metals like platinum to condense the oxygen of the air upon their surface and so to bring about oxidation or combustion. The opposite effect or what we call "hydrogenation," consisting in the bringing of the element hydrogen into reaction, has in recent years developed an equal importance and is now the basis of great industrial applications.

From about 1897 on, Prof. Sabatier, of Toulouse, France, working with various helpers, has studied this particular problem with great success and pointed out its great possibilities. These are presented in a very complete and interesting form in his work, "Catalysis in Organic Chemistry," an English translation of which by Prof. Reid, of Johns Hopkins University has appeared.

HYDROGENATION OF FATS. The earlier attempts to hydrogenate oleic acid, using metallic nickel as catalyser, with the production of stearic acid were made with the material as vapor and were not commercially successful. With the German patent to Leprince and Siveke in 1902, and the corresponding English patent to Normann in 1903, which hydrogenated oils in the liquid state, began the practical work, although developed by numerous other subsequent patents.

The commercial and economic importance of these processes is seen when we consider that the soap industry requires solid fats in larger amount than is readily available and that the cheapest and most impure of the vegetable and animal oils may now be converted into pure solid fats. From the cheap fish and whale oils can also be produced by this treatment inodorous edible fats. The addition of less than 1 per cent. of hydrogen suffices to convert cottonseed or other vegetable oil into a fatty body of at least the consistency of lard which product is odorless and very stable in character. So far as digestibility is concerned even whale oil appears to be fit for use as a food after being hardened. The iodine figure is cut down to a minimum indicating saturated compounds formed from unsaturated, while the specific gravity and melting point at the same time are raised. The only question that arises is the presence at times of traces of metallic nickel in the product, which may have some injurious effect, although that is as yet not established.

CATALYTIC REACTIONS WITH NAPHTHALENE. By the catalytic hydrogenation of naphthalene first carried out by Sabatier and Senderens two very valuable solvents have been obtained, tetrahydronaphthalene and decahydronaphthalene known technically as "tetralin" and "decalin." These are no made on a large scale in Germany and have proved very excellent substitutes for turpentine and in addition have special solvent powers, dissolving both rubber and celluloid. They are produced by the hydrogenation with metallic nickel as catalyst. Extreme purity of the naphthalene is essential as the catalyst is readily made inactive by poisons.

On the other hand, the catalytic oxidation of napthalene is, if anything, even more important.

By oxidation of naphthalene with sulphuric acid at a temperature of over 200° C. and in the presence of a catalyst like mercuric sulphate, phthalic acid is formed. As this is a most important material used in the manufacture of artificial indigo as well as the basis of a class of important dye colors, the process is of great importance. It is stated in this connection that at 275° the addition of 1 per cent. of mercuric sulphate to the acid causes the reaction to proceed with a velocity five times greater than that attained where the catalyst is absent.

Another illustration of this reaction is found in the Kjeldahl method of oxidizing organic nitrogen compounds, for the quantitative estimation of nitrogen, by means of hot concentrated sulphuric acid, containing small quantities of mercury or of copper, or of the sulphates of those metals. The influence of the catalyst is very marked; thus it has been found that, at a temperature of 275° the addition of 0.5 per cent. of mercuric sulphate to the sulphuric acid increases the velocity of oxidation of aniline threefold. Moreover, in this case, as in many others, the acceleration produced by the combined action of mercuric sulphate and cupric sulphate is greater than the sum of the accelerations brought about by each of these catalysts separately.

ACETALDEHYDE, ACETIC ACID AND ACETONE. A series of interesting and industrially important reactions, all catalytic in character, may be found starting with acetylene gas obtained from calcium carbide. The first reaction, that of hydration—

$$CH\!-\!CH + H_2O = CH_3.CHO,$$
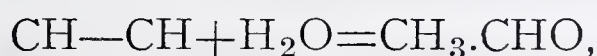
takes place when a current of acetylene is passed into an aqueous

solution of an acid (like sulphuric or phosphoric) in the presence of a mercury salt, which acts as a catalyst and the acetaldehyde produced separated. Or acetic acid may be formed at once by the interaction of acetylene, oxygen and the requisite amount of water in the presence of salts of mercury such as the acetate, sulphate or phosphate.

The catalytic decomposition of acetic acid accomplished by distilling it through a heated tube containing barium carbonate with the production of acetone and carbon dioxide was proposed already in 1895 by the late Dr. Squibb and is very satisfactory, a yield of about 90 per cent. of the theoretical amount being obtained.

HYDROLYSIS. The whole class of decompositions of organic compounds grouped under this generic name has been shown almost without exception to be facilitated by the action of catalysts. We shall not attempt to cover this wide field at present, but take only a single class of compounds, *viz.*, the naturally occurring fats as an illustration of catalytic methods in their industrial treatment.

The hydrolysis of fats by water alone is possible although slow in practice. In the Tilghman process, a mixture of water and fat is forced through coils at a temperature of 300°; with superheated steam under a pressure up to 15 atmospheres it is more successful, but never complete.

With acid as catalyst, however, the hydrolysis is perfectly satisfactory. It may be accomplished with sulphuric acid (4 to 6 per cent. reckoned on the weight of the fat taken) with the production of a high per cent. of solid fat acids suitable for candle-making.

Still more satisfactory is the Twitchell process in which the catalyst is a sulpho-aromatic fatty acid as naphthalene-sulpho-oleic acid. The process is operated at the ordinary pressure and can be carried out in open wooden tanks; 2 per cent. of the catalytic reagent suffices and the operation is completed in about an hour. The favorable results are due to the fact that the catalytic reagent is soluble both in the fat to be hydrolyzed and in the water. By thorough agitation with live steam a very perfect emulsion is therefore created, and in the presence of the strong aromatic sulphonic acid catalyst the reaction proceeds rapidly.

Saponification with alkaline catalysts. Lime or magnesia may be used as in the so-called autoclave process, using 12 to 14 per

cent. by weight of the alkaline-earth catalysts, or caustic alkalies, as in the manufacture direct of soaps as the product of the reaction.

The reverse reaction to the hydrolysis of an ester like the glycerine esters of the fatty acids is the *esterification* of a mixture of an alcohol and an organic acid. This kind of reaction is also greatly influenced by the action of catalysts. An illustration will suffice for this. When two parts of ethyl alcohol containing 3 per cent. of hydrochloric acid are heated with one part of benzoic acid, the yield of ethyl benzoate amounts to about 75 per cent. of the theoretical quantity and again when a mixture of two parts of the alcohol one part of the acid, and 0.2 part of sulphuric acid is heated for some time a 90 per cent. yield of ester is obtained. Solid catalysts like thoria and titanium oxide have also been used successfully for esterification.

It would take much more time than is available to enumerate the many organic chemical industries in which catalysis plays an important part. We note only in passing the use of driers such as manganese and lead compounds with drying oils, the use of accelerants in the vulcanization of rubber and the use of special catalytic reagents like Grignard's organo-magnesium compound and Friedel and Craft's aluminum chloride reagent in organic syntheses.

ENZYME REACTIONS. We have already given an account of enzymes, the organic catalysts produced in animal or vegetable life. A great variety of these substances are recognized. We may simply classify the best known. First, Enzymes inducing hydrolysis, which in turn may be sub-divided into the following reactions: *Saccharoclastic* reactions, or those which hydrolize the carbohydrates; hydrolysis of the glucosides and glycerides (*lipoclastic*); and protein hydrolysis (*Proteoclastic* enzymes). Second, Enzymes inducing oxidation or reduction: the *oxydases* and the *reductases*.

Each of these classes and subdivisions includes a number of definitely recognized and effective enzymes, upon the action of some of which are founded important industries and in other cases important vital functions. Both the industrial organic and the physiological chemist have found abundant ground for study and productive results in this field and it is constantly expanding. We cannot, however, at this moment more than indicate its existence.

In conclusion, we would say that the literature of catalysis is

already a considerable one and rapidly increasing. We would specially acknowledge our indebtedness for valuable information and suggestions to "Sabatier's Catalysis in Organic Chemistry," translated by Prof. Emmet Reid, to Rideal and Taylor's "Catalysis in Theory and Practice" and to Henderson's "Catalysis in Industrial Chemistry."

"THE ALUMINUM AGE."

By Ralph R. Foran.

(Assistant Professor of Technical Chemistry, Philadelphia College of Pharmacy and Science.)

Aluminum was discovered in 1827 by Wöhler, who isolated it in the form of an impure, gray powder, by decomposing aluminum chloride with metallic potassium. Later in 1845, he obtained the metal in small, metallic globules, by a modification of the same process. He made no further use of the discovery, except to determine the chief properties of the metal. It remained for H. St. Clair Deville, in 1854, to isolate the metal in an almost pure state, by decomposing aluminum chloride with metallic sodium. Under the patronage of Emperor Napoleon III he carried on research and in two years extracted fifty to sixty pounds of the metal, which sold for $260 a pound. The Emperor, a lavish spender, had a state coach, the bottom of which was made of solid aluminum. It is said that this saved his life, for when a bomb was exploded under his carriage, although many bystanders were killed, he was protected by the metal bottom of the carriage and escaped unhurt. And so it seems that the money was, after all, well spent.

By 1878 the industry was well established in France, but the price was still high—about $13 a pound. About this time a works was started in England, but it was not until 1884 that manufacture began in the United States. Colonel William Frishmuth, who had a plant near the Richmond coal wharves in Philadelphia, turned out about 200 pounds in this and the following year. The aluminum cap or apex of the Washington Monument was cast by him. It weighed 8½ pounds and cost about $15 a pound—about as expensive as silver. Frishmuth's patented process was intended to be an improvement on the Deville method, but there seems to be a question whether he actually produced aluminum in commercial quantities by his method. Much of his output consisted of remelted scrap, obtained from abroad.

The Cowles Electric Smelting and Aluminum Company in 1886 was the first to use the electric furnace for the practical production of aluminum. Their process, however, yielded only alloys, containing up to 20 per cent. of aluminum. Their work was the first great advance in electro-metallurgy and showed the way for further improvement in the recovery of aluminum.

Among the workmen at the Cowles plant in Lockport, N. Y., was one Charles M. Hall, who, while a chemistry student at Oberlin College, had discovered the method which is used today universally. He found that bauxite or alumina, an oxide of aluminum and very plentiful, would dissolve in molten cryolite, a white mineral occurring in great quantities in Greenland. He also found when this solution was decomposed by the electric current, that he obtained aluminum. In the three years that Hall spent at the Cowles plant, he was unable to commercialize his process, but with the Pittsburgh Reduction Company at Niagara Falls he was more successful, so that in 1889 the output was 50 pounds a day. The price of the metal dropped to $4 a pound. This was due to the improved process and relatively cheap current furnished by the Niagara Power Company, which had just completed its first installation.

The year 1889 was truly epochal in the history of aluminum, for it was during this year that Hall's processes were patented, and that the Pittsburgh Reduction Company, later the Aluminum Company of America, started the manufacture of aluminum commercially.

In this same year, Héroult in France, patented a process, similar to the Hall method, which was and is still used abroad. Consequently the process of recovering aluminum by electrolyzing alumina in molten cryolite, is generally known as the Hall-Héroult process. Although the original patents have since expired, the metal is still obtained in much the same manner in all countries. Coincident with the progress in aluminum recovery has been the development of electric power, of which enormous quantities are necessary. In 1886, the Cowles Brothers had built a direct current generator of 30-horsepower capacity, which was called "The Colossus." Nowadays, this machine would be a pigmy as compared to the installations available for producing power.

With the impetus in production about this time, 1890, extravagant claims were made for aluminum. The pure metal had been the dream of chemists. Now that it was no longer rare, all sorts of uses were suggested. "Railway trains would be made imperishable and track wearage reduced to a minimum. Aerial navigation would be expedited. Military equipage, ammunition and guns would be lightened." The metal was popularly described as being "as strong as steel and but little heavier than wood." The presence of its ore in the earth's crust in large excess even of that of iron it-

self would furnish inexhaustible sources for the new Aluminum Age. A company was organized in Ohio for the purpose of manufacturing aluminum shoe soles. Although the metal is not now used for shoe soles, it is used for shoe heels. Solid aluminum bath tubs made their appearance, as did aluminum walking sticks and billiard cues. The Bryden Horse Shoe Company of Catasauqua, Pa., made aluminum racing shoes with a steel rim, weighing two ounces each, which sold for $1.25 a set. The manufacturers evidently were trying to satisfy the wants of the racing men who claimed that "an ounce off a horse's hoof is equal to a pound off his back."

The domestic price of aluminum in April, 1891, was $1.50 a pound. Later in the year this was reduced to 50 cents a pound, due to the falling of the price abroad. Since then, except for a time during the World War, the price of the metal has never exceeded this figure—50 cents. It is now quoted at 22 to 23 cents a pound, in 50-ton lots.

As a matter of local interest, it might be mentioned that in 1893, the Tacony Iron and Metal Company of Philadelphia, contracted to deposit a coating of aluminum on the iron columns for the Philadelphia City Hall tower. The coating was for the purpose of preserving the iron from the action of the elements, aluminum being unaffected. Several years later the columns had lost their brightness and were eventually removed. Upon examination it was found that instead of aluminum, an alloy of aluminum and tin had been used. The late Professor J. W. Richards, in this year, strongly recommended that our cents should be made of aluminum. He said: "The advantages of light, clean aluminum over heavy, poisonous copper are self-evident." The United States Mint in 1865 had experimented in the making of aluminum coinage, but nothing ever materialized. During the war, aluminum coins were issued in France and Germany and even now in France, aluminum bronze coins are to replace the paper notes of small denomination.

Aluminum culinary utensils were first put on the market in 1893, by the Illinois Pure Aluminum Company, of Lemont, Ill. For cooking utensils, aluminum is the metal *par excellence*. It is light, easily cleaned, noncorrodible and its salts are non-poisonous. Weight for weight, it is not as good a conductor of heat as copper, although it has four times the heat conductivity of iron. Comparing an aluminum and a copper vessel of equal thickness, the aluminum ves-

sel has the greater heat conductivity, which means, of course, a saving in fuel. At the present time, aluminum is worked into all manner of cooking utensils and culinary aids. The advertised brands of domestic aluminum ware are reliable and sold on guarantee, but there is an avalanche of worthless foreign and domestic ware on the market, "made to sell." Since 1919, Germany has increasingly flooded this country with every conceivable manner of aluminum ware, made from surplus war materal. Some of it is good, but most of it is cheap and not substantial. There is also much domestic ware of the same type.

As early as 1897, aluminum powder and leaf had replaced silver powder and leaf, for many purposes. Today, aluminum foil is used, to replace lead and tin foil for wrapping candy, chewing gum, tea, tobacco, cheese, etc.

Count Zeppelin used aluminum in 1900, in his first airship and in the later and larger type, used during the war, each ship contained about nine tons of the metal and its alloys. The Zeppelin works at Staaken have within the last few years placed a motorboat on the market, made entirely of "duralumin," an alloy containing 94 per cent. aluminum, 4.5 per cent. copper and 0.5 per cent. magnesium. It is proposed to use such boats as lifeboats on ships.

On January 1, 1907, the Pittsburgh Reduction Company changed its name to the Aluminum Company of America, as more correctly indicating the nature of its business. From its organization in 1889, the company has enjoyed a monopoly of aluminum manufacture in this country. It turns out one-half of the world's production. The company started in 1889 with an authorized capital of $1,000,000 which had increased to $20,000,000 in 1916. Up to this time it had invested about $70,000,000 of undivided profits in its business. It is estimated that the present market value of the $20,000,000 capitalization is probably over $150,000,000. In 1906 it was predicted that with the expiration of the Hall patents, there would be "a battle royal between the the Aluminum Company of America and its new competitors." Nothing of this sort ever occurred. In 1908, an official of the company, appearing before the Ways and Means Committee in regard to tariff legislation, said that the then present price of 20 to 22 cents a pound was as low as aluminum could be manufactured under American conditions of manufacture. He also claimed that the position of the Aluminum Com-

pany of America was due, not to combinations, control of raw material, etc., but to meritorious patents. And yet in 1912, the United States Court in Pittsburgh entered a decree annulling alleged unlawful contracts of the Aluminum Company of America with the General Chemical Company, The Norton Company, the Pennsylvania Salt Manufacturing Company, Gustave A. Kruttschnitt and J. C. Coleman and forbidding the former company from participating in any combination or agreement to control the output or prices of aluminum. It was shown that the company had agreements with the first three companies mentioned, forbidding their engaging in the manufacture of aluminum or selling bauxite to any one else, and with Gustave Kruttschnitt and J. C. Coleman, not to manufacture or sell aluminum east of Denver for twenty years from November 16, 1910.

In 1914, the Southern Aluminum Company, a subsidiary of L'Aluminum Francaise, with $6,000,000 capital, began building a plant at Badin, S. C. As a result of the European situation and financial difficulties, the plant was never completed and in 1915 it passed into the control of the Aluminum Company of America. The prospect of cheaper aluminum through domestic competition was not realized. And now the International Aluminum Company proposes to set up a plant at Nitro, W. Va., the site of the war-time smokeless powder development, using a process in which aluminum sulphate is electrolyzed in oleum. Some of the copper companies may enter the field, as aluminum is a dangerous competitor, both for alloy castings and electrical work.

While it is true that the Aluminum Company of America has never gouged the aluminum buying public, not even raising the price during the war, it is a monopoly—a word which brings to the mind of the average citizen, thoughts on trusts, business agreements in restraint of trade and the tariff. It is of interest to know that the price of aluminum in the United States has been increased in the past in about the same proportion as the duty on the foreign metal has been increased.

The use in cooking utensils is one of the mainstays of the business, but large quantities of aluminum and its alloys are used for many other purposes. The automobile industry uses millions of pounds annually and who knows but that Henry Ford wanted Muscle Shoals whereat to produce the aluminum for his "Feather-

weight Flivver." And at that, the aluminum automobile is not a theory. Experimental cars have demonstrated that the durability can still be maintained with a great saving in weight and an increased mileage. The problem of a diminishing gasoline supply will hasten the coming of the lightweight aluminum car.

Substantially one-third of the Liberty motor was aluminum. It was used wherever possible—engine beds, crank cases, pistons, oil pumps, camshaft housings, etc. It was also used for the gasoline tank, fuselage, hood, cowling and seat backs. The all-metal planes would be impossible without aluminum. Fabric wing coverings are replaced by duralumin. The framework is tubing of the same alloy.

The war uses of aluminum and its alloys were many and varied. The Germans used much aluminum as a substitute for copper, even for dynamo windings. Until the beginning of the war, no aluminum was produced in Germany, although a great many aluminum products were manufactured there from metal imported from Switzerland. The French used an aluminum alloy for helmets and all of the armies used the metal in mess equipment and for many other purposes to which its lightness adapted it. Every American soldier wore at all times identification tags of aluminum and his trusty gas mask contained parts made of this metal.

The metal is finding increasing use as an electrical conductor. Although for the same thickness of wire it has only about 60 per cent. of the electrical conductivity of copper, taken weight for weight it is a better conductor. It is used mainly in the West and South for electrical transmission lines and in the manner used has 80 per cent. of the weight of copper cable of equal conductance and is 57 per cent. stronger. There are lengths of cable up to 275 miles in use, carrying up to 150,000 volts. In 1913, 15 per cent. of the output of aluminum was used for transmission cables.

For the future, the alloys of aluminum promise most perhaps. Alloys of the type of duralumin and magnalium are being used increasingly. In the last few years a great deal of research has been carried on in this country and abroad, with the end in view of defining those alloys which are at once light in weight, strong and non-corrodible.

In closing, a little introspection might not be out of place. Aluminum is one and one-half times more plentiful than iron and

four thousand times more plentiful than copper. Iron and copper were both known to the ancients. Aluminum has been known only ninety-six years and in common use for only thirty-three years. Professor Richards hazarded the thought that it would surpass lead in 1930 and zinc in 1940, and both of these metals were discovered in prehistoric days. It is conceded that, in the light of its peculiar properties and manifold applications, it is exceeded only by iron and copper. That it will surpass copper within the next fifty years is not a rash estimate. It will then be next in importance to iron. And then what?

ANIMAL-EATING PLANTS.

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The great and fundamental rôle of green plants in the world's economy is that of constructing highly complex organic compounds for food out of simple, inorganic, raw materials. This food, part and parcel of their very bodies, is eaten by animals whose chief and contrasting rôle is that of breaking down the plant food into its simplest elements.

The raw materials which constitute the ordinary diet of green plants represent salts of various metals, such as nitrates, phosphates, sulphates, *etc.,* and water which they absorb from the soil, and carbon dioxide, which they inhale from the air during sunlight.

There exist, however, about five hundred species of green plants which have become dissatisfied with the mere common diet of their relatives in the vegetable world and have acquired, in addition, the luxurious appetite for the flesh and blood of animals. These exhibit a variety of devices for the allurement, capture, imprisonment, digestion and absorption of their prey.

Chief among these animal-eating or carnivorous plants are the sundews, fly-traps, pitcher-plants, bladderworts and butterworts. In each it is the leaves which have become modified for the purposes indicated.

The Sundews.

The sundews are curious, small, bog plants that are mainly members of the genus *Drosera,* which comprises eighty-four species, occurring in tropical, warm temperature and cool temperate regions of both hemispheres. Each of these possesses a rosette of leaves that arise from a greatly reduced root system.

The shape of the leaves varies depending upon the species, although it is frequently rotund, spatulate or filiform. The whole upper surface of the leaf-blade is covered with glandular tentacles, often of a wine-red color. The glandular heads of these are covered with a viscid secretion that glistens in the sunlight like dewdrops, a phenomenon that accounts for the common name assigned to the members of this group. The tentacles in the central part of the leaf-blade are short and erect and their stalks are green. Toward the margin they become longer and more inclined outward and their stalks are of a wine-red to purple color.

When examined under the microscope, each tentacle shows a slender pedicel terminating in a gland. A conducting bundle containing spiral vessels and simple vascular cells is observed to come off of a fibrovascular bundle in the leaf-blade and run through the center of the pedicel to the gland. Upon entering the gland it is enlarged and spread out into a number of tracheids. These centrally placed tracheids are surrounded by a protective sheath (endodermis), outside of which are two layers of secretory (epidermal) cells with wine-red, granular contents, the outer layer of which is

Fig. 1. *Drosera rotundifolia,* a common sundew found in northern peat bogs.

palisade-like. These glands are commonly oval, excepting the extreme marginal ones, which are considerably elongated. They secrete, absorb and are acted upon by various stimulants.

Darwin[1] has shown that when a small object is placed on the tentacles in the center of the leaf these transmit an impulse to the marginal tentacles. The nearer ones first respond and slowly bend toward the center and then those farther away, until finally all become bent over the object. The time essential varies from ten seconds to five or more hours, depending upon the nature, contents

and size of the object, upon temperature, and also upon the age of the leaf.

Again, if the glands are repeatedly touched or brushed or if chemical substances are placed on these the marginal tentacles curve inward. The bending part of each tentacle is confined to a limited space near the base. Not only the tentacles but the blade of the leaf becomes much incurved when any strongly exciting substance is placed on the blade.

The time during which the tentacles and blade remain curved over the object varies according to the temperature, character of object, age, *etc*. Doctor Nitschke[2] found that during cold weather both the blades and tentacles re-expand within a shorter period than when the weather is warm. Darwin[3] found that the tentacles remain clasped for a much longer period over objects which yield soluble nitrogenous matter than over those yielding no such matter. After a period varying from one to seven days the tentacles and blade re-expand and are then ready to again respond. It has been shown by the same authority that as soon as the tentacles become inflected over an object yielding soluble nitrogenous matter their glands pour out an increased amount of secretion which becomes acid in nature. These glands, moreover, continue to secrete as long as the tentacles remain closely inflected.

In nature, small insects catch sight of the glittering drops on the tips of the reddish tentacles, and, mistaking these for honey, alight upon the leaf. They become instantly entangled by the viscid glandular secretion. They try to stroke the viscid fluid off of their legs, but only besmear themselves more. Soon they become covered with the sticky substance, which occludes the orifices of their breathing tubes (tracheæ) and they perish in a short time (one-quarter of an hour according to Doctor Nitschke) from suffocation. The surrounding tentacles bend over the insect's body and clasp it on all sides. A digestive juice containing a proteolytic enzyme of peptic character and an acid is now poured out of the glands. This digests the flesh and blood of the insects caught. The water-insoluble chitinous parts of the body are left on the surface of the blade. If the insect be large, the bending of the tentacles is augmented by the inflexion of the whole surface of the leaf-blade, which assumes a concave shape. With the tentacles also curved over, the whole leaf simulates a closed fist. The glands then absorb the soluble nitrogenous material which is assimilated by the plant.

Among the insects caught by the sundews are gnats, flies, ants, beetles, small butterflies and dragonflies. The last named are captured by the co-operation of two or three adjacent leaves.

The Fly-Traps.

The fly-traps comprise two species, *viz.*, the Venus Fly-Trap (*Dionæa muscipula*) and the Submerged Dionæa (*Aldrovanda vesiculosa*).

The Venus Fly-Trap is restricted to damp localities of a coastal

Fig. 2. A patch of Venus Fly-Traps growing near Wilmington, North Carolina.

plain strip extending for about fifty-five miles north and forty-five miles south of Wilmington, North Carolina, and nowhere over fifteen or twenty miles in width.

Each plant shows a rosette of modified leaves which together are rarely more than six or seven inches across. From the center

of these arises a flower stalk bearing a cyme of white flowers which open from April to June.

Each leaf consists of a winged petiole that is studded on both surfaces with small, brown, stellate hairs. The petiole is truncated in front and contracted to the midrib, which suddenly broadens out into a blade composed of two symmetrical halves that can fold together along the line of the contractile and irritable midrib region. Along the margin of each half of the blade are long, stiff, non-irritable bristles, which, on closure of the blade, interlock with each other. On the center of the upper surface of each half of the blade are three spine-like, sensitive hairs disposed as angles of a triangle. Each of these sensitive hairs is composed of elongated cells whose protoplasmic contents show movement. At the base of each is a cylindrical mass of small cells which permits the stiff hair to be bent over. These sensitive hairs are highly irritable and capable of receiving and transmitting a stimulus. Further, over the entire upper surface of the blade are numerous, closely-set, sessile glandular hairs which, after repeated irritation, secrete an acid digestive juice. Each of these, as observed under a microscope in surface view, consists of a rosette-arranged set of cells composed of four to twelve cell radii filled with a crimson-claret pigment.

Each sensitive hair consists of a somewhat elongated structure composed of three parts, viz., base, highly sensitive joint, and insensitive shaft. The base consists of large epidermal cells enclosing a prolongation of mesophyll cells within, that can receive and propagate a stimulus from the sensitive joint to the leaf interior. The joint consists of elongated columnar cells that enclose similar columnar mesophyll cells with soft, elastic walls. The shaft cells are elongated, thick-walled and almost insensitive.

When a stimulus is applied to any sensitive hair, this affects the joint cells and causes upsetting of turgidity and exudation of liquids with a consequent contraction of the elastic cells. The action is propagated to the midrib region where the cells, by contraction along the upper surface and expansion along the lower, cause closure of the halves.

Macfarlane[4] has shown that when an insect alights on a leaf of *Dionœa,* one hair must either be stimulated twice or two hairs on the same leaf at slight intervals apart in order to cause closure. The caught insect produces increased stimulation and a gradual tightening of the lamina occurs under the repeated stimuli until the

halves become closely locked. The glandular hairs now pour out an acid digestive secretion which digests the flesh and blood of the insect's body. The soluble nitrogenous substances are then absorbed by the glands and assimilated.

Dr. J. S. Hepburn,[5] of the Constantine Hering Laboratory, Hahnemann Medical College, of Philadelphia, recently found that the secretion of the leaves of *Dionæa* contained a protease which was active in the presence of 0.2 per cent. hydrochloric acid. This enzyme, therefore, resembles pepsin of the gastric juice of man, which also acts in a 0.2 per cent. hydrochloric acid medium.

Dr. J. M. Macfarlane, of the University of Pennsylvania, who with Doctor Canby and Charles Darwin have separately investigated the structure and physiological activities of this plant, reports that two touches one-fourth to one-third of a second apart will not produce closure of the halves, though a second stimulus that is from 1 to 120 seconds apart from the first will effect closure, also that it is not essential for the stimulus to be on one hair, that a prick sets off the trap at once due to liquid escaping from turgid cells, and further, that all muscle stimulants, mineral acids, and ammonia effect closure of the trap.

Among the insects caught by *Dionæa* are earwigs, millipedes, flies, ants, wood-lice and dragonflies. The length of time required for the digestion of their softer parts and the absorption of the soluble products of digestion varies. During this time the trap remains closed. Darwin[6] cites four instances in which leaves after catching insects never reopened but began to wither. Mrs. Treat,[7] who made observations on plants cultivated in New Jersey, noted that "five leaves digested each three flies and closed over the fourth, but died soon after the fourth capture." The power of digestion posssssed by *Dionæa*, accordingly, is more limited than that of *Drosera*, which has been known to capture and digest many insects in a shorter period of time.

Aldrovanda vesiculosa, which might well be called a "Submerged *Dionæa*," is a relative of the Venus Fly-Trap. It is a floating aquatic plant found widely distributed in shallow ditches and ponds over the old world from Europe to Australia, but nowhere abundant. This plant is entirely devoid of roots, but possesses a slender stem which bears whorls of modified leaves at its nodes. Like the Venus Fly-Trap, each leaf shows differentiation into a winged petiole ending in five narrow processes that connect with a

terminal, rounded, incurved blade, divided into equal halves by a sensitive midrib, but the midrib projects beyond the summit of the lamina as a bristle. Long, rigid, spiny bristles extend from the petiole and are thought to prevent the approach of animals unsuitable as prey. The margins of each half of the blade are bent inward and their rims are studded with short conical teeth. Projecting from the upper surface of the midrib and along a line describing the inner third of the upper-blade surface are a number of sensitive hairs and short-stalked, disc-shaped glands, while over the outer portion of the surface are to be noted a number of scattered stellate hairs.

Larvæ of aquatic insects and small species of Crustaceans such as *Cyclops, Daphnia* and *Cypris,* swimming by, occasionally brush against the sensitive hairs and the two halves of the blade close together just as in *Dionæa* and the animals are entrapped. When they attempt to escape through the place where the margins of the blade meet, they find the conical teeth prevent their egress. They die in the trap and when the latter are forced open and examined a couple of weeks later they only contain the chitinous skeleta.

The Pitcher Plants.

The pitcher plants are for the most part found in bogs. Their main representatives belong to the genera *Heliamphora, Sarracenia, Darlingtonia, Nepenthes* and *Cephalotus.* The pitcher itself represents the hollowed-out midrib of the leaf in the first four-named genera and an inpouching of an ordinary leaf in the last-named genus.

Heliamphora [8] is represented by a single species (*H. nutans*), which is only found on and around the base of Mount Roraima, between British Guiana and Venezuela. Here it flourishes in widespreading, dense tufts in wet places where the grass is short. It has a rosette of red-veined pitcher-leaves and delicate white flowers raised high on red-tinted stems. Along the entire length of the pitcher are two broad wings. The pitcher itself represents a hollowed-out midrib which is tubular in shape, becoming gradually broader from base to mouth and ending in a small lid. Over the entire outside of the leaf are nectar glands and upward-directed hairs. The nectar glands secrete a sweet fluid which entices insects, so that this surface can be termed the alluring surface. Nectar

Fig. 3. *Sarracenia purpurea* in bloom. Photographed in Ocean County, New Jersey. This pitcher-plant is our common northern species.

glands also occur on the inner surface of the lid. Next, the upper one-third to one-half of the inner surface of the pitcher is covered with downwardly projecting hairs and nectar glands. This surface can be called the attractive and conducting surface. A smooth surface follows, which in turn is succeeded by a detentive surface in the lower part of the pitcher, composed of mostly smooth-walled cells, a few of which bear short hairs.

Sarracenia[8] is represented by seven species, all of which are confined to Eastern North America except *Sarracenia purpurea*, which extends west to Western Minnesota and West Central Canada. Their pitchered leaves are of varying form and color design, depending upon the species. Frequently they are long-funnel shaped, tubular or vase-shaped. The color of every species varies with its age as well as extent to which it is exposed to bright sunshine. In some respects the form of pitchers resembles *Heliamphora*, but there is only a single wing present and further the lid is considerably larger.

In all we find the pitchers showing an alluring outer surface covered with nectar glands, but devoid of the upwardly directed hairs seen in *Heliamphora*, an attractive inner-lid surface, marked with numerous downwardly directed hairs and nectar glands which lead the insect toward the next or conducting surface. This is either nearly smooth (*S. purpurea*) or it presents delicate, downwardly projecting processes and on which the insect loses its foothold, also (excepting *S. purpurea*, which next shows an intervening glandular zone) a lower detentive zone, in the bottom of the pitcher, which contains a watery fluid and whose surface, save its lowest portion, is marked by the presence of many elongated, downwardly directed, thick-walled hairs, which prevent the ascent of insects that have fallen into this zone from above. Glands are also present on the upper part of the detentive surface.

Darlingtonia[8] is represented by a single species, *Darlingtonia californica*, which grows in mountain swamps and borders of small streams at altitudes of 1000 to 6000 feet from Plumas County in the Sierras of California northward to Jackson and Josephine Counties in Oregon. Its underground rhizome gives rise to pitchered leaves which are from one and one-half to nearly three feet in height and spirally twisted in about a half-revolution. Each pitcher expands near the summit into an inflated hood, which exhibits a circular opening up to an inch in diameter on the under side. The

Fig. 4. *Sarracenia drummondii,* a southern species, showing open pitchers and younger pitchers with closed lids and lips. Photographed in Mobile County, Alabama, where the mature pitchers commonly attain a height of 18 to 28 inches.

dome of the hood is spotted with large, thin, translucent areas. A wing extends along the pitcher from rhizome to its orifice. At the upper and outer edge of the opening is a moustache-shaped append-age which possesses stiff hairs, all of which point toward the pitcher

Fig. 5. Darlington's Pitcher-Plant (*Darlingtonia californica*), a western species showing the twisted pitcher and the bilobed flap. Photo-graphed in Plumas County, California, where mature pitchers attain a height of 20 to 30 inches.

opening. The color of the pitcher is green, blotched with red and yellow. Within and about the opening and on the bilobed append-age are alluring glands which secrete a nectar attractive to insects. The nectar is also secreted by glands along the wing. An insect

creeping over the exterior of the pitcher is enticed to the nectar along the wing, which it follows up to the orifice, where the honey is sweetest. Flying insects are attracted to the pitcher by its mottled and colored features. They alight on one of the flaps of the appendage and follow its curve, which narrows to the orifice. Sharp bristles in the path pointing toward the orifice make it the natural direction for the insect to travel. Upon reaching the end of the path, it is tempted farther by honey glands within the opening of the pitcher, which it next visits. When satisfied and ready to leave, the translucent areas on the hood above, like illuminated windows, entice it away from the opening by which it entered. The insect sees no means of escape, nothing but hairs on the inner surface of the pitcher pointing downward and which direct it to the dark detentive pit below, where it drowns in the watery secretion.

By far the most beautiful and gracefully shaped pitchers are those belonging to the genus *Nepenthes,* which is represented by about sixty-eight species that are mainly indigenous to the East Indies, with headquarters in North Borneo and with Mount Kina Balu as a center. Many of the plants are continuously exposed to a moist, dripping atmosphere.

Each of the modified, pitchered leaves shows a petiole (usually winged) which widens into an expanded blade, the midrib of which is continued as an elongated tendril which expands into a terminal winged pitcher. The pitchers show a large variety of shapes and color designs, depending upon the species. Frequently they are tubular, goblet or cornucopia shaped. Each pitcher has a hinged lid which varies from small elliptic to large heart or kidney-shaped. The tendril is sensitive to contact stimuli and often winds about a limb of a tree. The pitchers, partly filled with a viscid watery secretion, either hang suspended in the air from the tendril or rest on the ground.

One of the largest pitchers found in this group is that of *Nepenthes Rajah,* a species found on Mount Kina Balu along the north coast of Borneo at an altitude of 5000 feet. It has leaves which, exclusive of petioles, are eighteen inches long, and the pitchered portion is six inches in diameter and twelve inches in length, with a circumference of nineteen inches. The lid is ten inches long and eight inches broad. The pitchers rest on the ground in a circle. The color of the pitchers is deep purple. The color of the lid por-

tion is lavender, shading to green at the edges. One pitcher noted by Spenser St. John [9] held four pint bottles.

Nepenthes Edwardsiana, another large pitchered form reported by St. John,[10] is an epiphytic climber found on the north side of Mount Kina Balu at altitudes of 6000 to 8000 feet. One plant measured by this explorer was twenty feet long and had a large cylindrical pitcher on every leaf, twenty-one and one-half inches long and
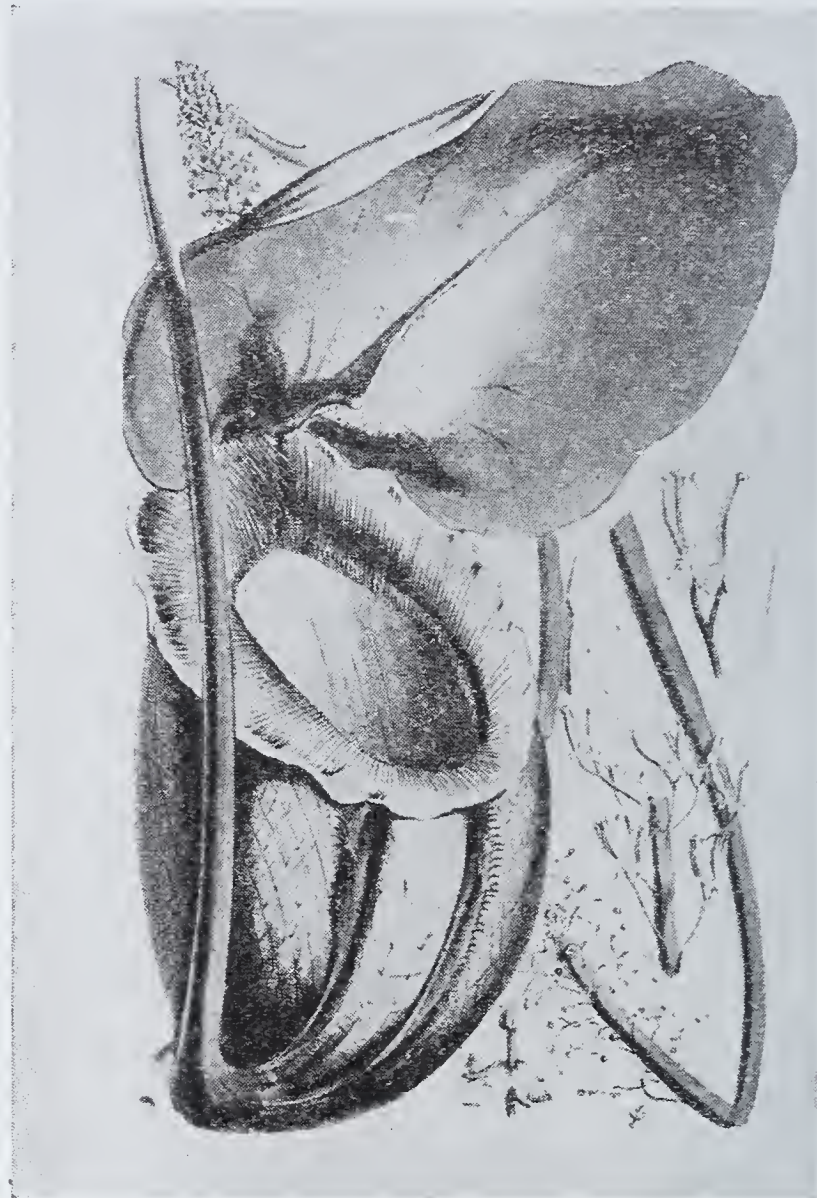
Fig. 6. *Nepenthes Rajah,* an East Indian species of pitcher-plant.

two and one-half inches broad. The base of the pitcher was bright pea-green, the remaining surface a brilliant brick-red. The circular lid was red in the center and green around the margin.

The lower surface of the petiole, lamina and the whole external surface of the tendril and pitcher are covered with alluring nectar glands. These alluring glands also occur along the stem. Their secretion entices insects to the pitcher mouth or lid. Around the

mouths of the pitchers of nearly all of the species is a corrugated rim on which are parallel ridges, which are usually extended as teeth that are inclined downward into the pitcher cavity. The surface of this rim is smooth and polished, so affording a poor foothold for insects. Around this rim, in the region of the teeth, are the openings of deeply sunken marginal glands which pour forth a very
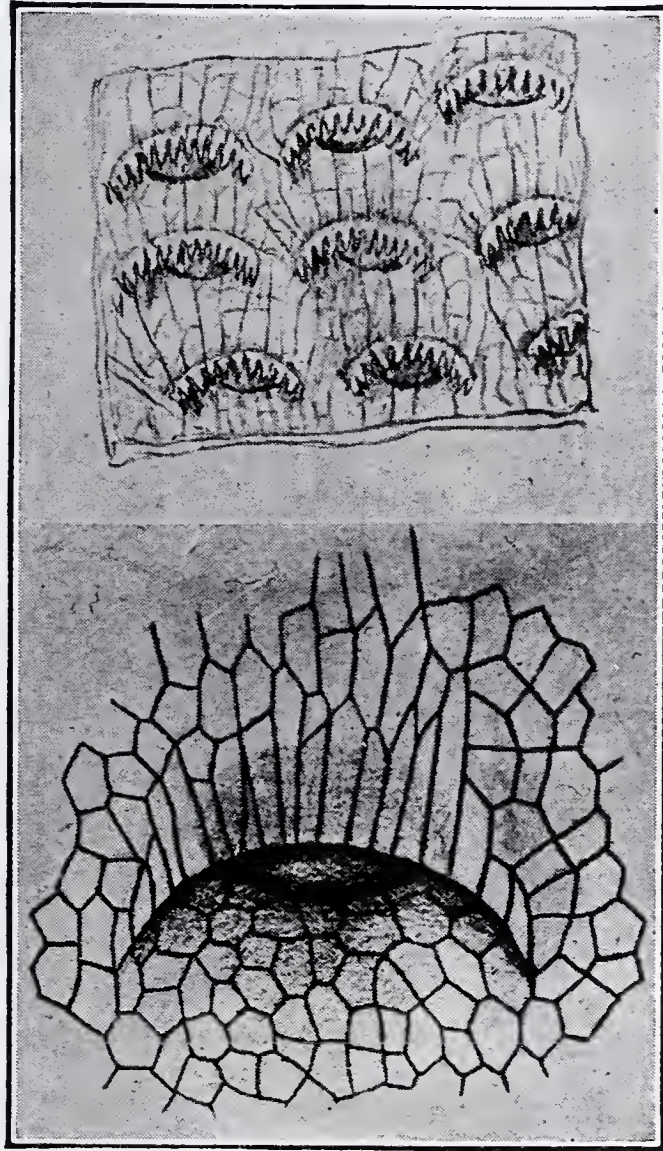
Fig. 7. Digestive glands of *Nepenthes,* each imbedded beneath a projecting flap. A group of the glands is shown in the upper section. a single gland at a higher magnification in the lower section.

sweet nectar, attractive to insects. The inner surface of the lid is usually dotted with attractive glands.

In many species of *Nepenthes* the entire inner surface of the pitcher cavity constitutes the detentive surface. It is lined with a smooth epidermis that is uniformly studded with glands which secrete a digestive juice containing a proteolytic ferment and absorb

the soluble products of digestion. In many others the upper sur-
face of the cavity is smooth, forming a conducting surface, while
the lower one-half or one-third is alone detentive. Insects lose
their foothold on the conducting surface and fall into the watery
secretion at the bottom of the pitcher.

Cephalotus has but one species, *C. follicularis,* which is native
to swamps of South West Australia. It has short creeping rhi-
zomes, which produce annually one set of five foliage leaves and

Fig. 8. *Cephalotus follicularis,*
an Australian pitcher-plant.

later a set of pitcher-leaves, which rest on damp soil. The pitchers
externally are equipped with winged ridges, which provide a handy
means of ascent to the mouth for creeping animals, while their lids
are half-closed and mottled with white areas and purple veins and
are often mistaken for flowers by high-flying insects. In minute
details of structure the pitchers are surprisingly like those of *Sar-
racenia* and *Nepenthes.* The exterior of the stalk is studded with
alluring glands. The margin of the pitcher is corrugated and
inflexed, and all over this area and exterior of corrugation, as well
as on the inner lid surface, are an abundance of honey glands
(attractive surface). Just inside of the margin is a circular, shelf-

like ingrowth consisting of downward-directed cells which resemble the conductive surface of *Sarracenia*. The remainder of the inner surface constitutes the detentive surface.

At the bottom of the pitcher on either side are two beautiful crimson to crimson-claret patches. These have sunk in them huge, many-celled glands which have a fibrovascular bundle terminating in their base. The glands secrete an acid digestive juice which partly dissolves the animal captives. A viscid secretion partly fills the pitcher cavity.

As to relations of the pitchers of these several types of curious plants to animals it may be said that insects, spiders, *etc.*, are attracted to the plants partly by the brilliant colors of their pitchers and partly by the nectar drops exuded by honey glands. They make their way to the exterior of the lid (or appendage in *Darling-tonia*), where the secretion along the outer margin is plentiful. From here they move to the inner surface of the lid and sip the honey. Tempted further by the sight of nectar ahead and often by hairs pointing downward, they step inside the pitcher on to the con-ducting surface. Upon reaching this surface they waver, slip off and fall into the lower part of the pitcher which is the water holding region. They make numerous attempts to escape, but find exit im-possible on account of the downward-projecting hairs. They drown in the liquid and their bodies are either decomposed or digested by a digestive juice secreted by glands lining the lower portion of the pitcher cavity.

The animals caught by these pitcher plants are various. While insects constitute their chief prey, slugs, spiders and rodents have been recorded by observers as having been captured by a number of them. Burbidge [11] observed several *Nepenthes* in North Borneo visited by a small rodent, which, while perched on the margins of the pitchers, bends its head and neck and scoops out the caught insects and devours them. The same writer states that if it attempted such action with *N. bicalcarata,* the two sharp spurs with which the pitcher of this species is provided catch it by the neck and tumble it into the pitcher.

Macfarlane [12] has carefully observed the relations of *Nepen-thes* to animals. He states in part that "running insects such as ants and cockroaches are their principal prey. Cockroaches run up the stem and may pause to sip nectar from the alluring stem glands. Reaching the base of the leaf, they may pass along it, attracted by

the presence of honey drops there. They almost invariably run along its under side to shelter themselves from enemies and the hot sun. Moving on restlessly and sipping from nectar glands as they advance, they reach the tendril. The ventral wings and the areas between are more beset with alluring glands than is the outer part of the pitcher, and along this they often run till they reach the

Fig. 9. A flowering plant of *Utricularia vulgaris*, a blad-
derwort. Note dissected leaves, some of which are
modified as bladder-like traps.

orifice or lid. The lid glands of the inner surface prove a great attraction, but their secretion does not compare with the marginal glands. Straining to reach the orifices of the glands, the insect visitors often overreach themselves after a few efforts and tumble into the pitcher cavity, and in rare cases is escape again possible."

Mr. Low, who accompanied Spenser St. John on his travels in

North Borneo, found a drowned rat in one of the pitchers of *Nepenthes Rajah.*[9]

The character of the enzymes found in the pitcher secretions has been investigated by Hepburn.[18] This author found a tryptic enzyme in *Nepenthes* which was active in a slightly acid medium. No proteolytic enzyme was found by him in the secretions of *Darlingtonia,* while the *Sarracenias* he investigated were found to possess proteolytic enzymes. The protease in the pitcher liquor of *S. flava* and *S. minor* acts best in 0.2 per cent. hydrochloric acid, while that present in *S. purpurea, S. rubra, S. Sledgei* and *S. Drummondii* acts best in an alkaline solution containing 0.5 per cent. or less of sodium carbonate. Dakin[14] found a protease in the pitcher liquor of *Cephalotus.*

The Bladderworts.

The bladderworts or *Utricularias* are aquatic plants which are found in pools and bogs of various parts of the world, with their centers in South America and the East Indies. The plants are rootless and according to the season of the year sink to the bottom or rise to near the water surface. They have finely dissected submerged leaves, some of which are specialized as bladder-like traps which allow the entrance but not the escape of small animals. Each of the traps represents a greatly modified inflated leaf of vesicular form and usually about one-sixth to one-fifth of an inch in diameter. From the margin of its opening project stiff bristles. There is an upper and lower lip present. The lower lip is greatly thickened and provided with a cushion-like process that extends into the bladder. From the upper lip is suspended a thin elastic valve, the free edge of which rests upon the inner surface of the lower-lip cushion and closes the opening.

Small animals, including crustaceans like *Cyclops* and *Daphnia,* as well as larvæ of small insects and worms, enter the bladders, either because they seek a sheltered harbor for a time from larger prey or because they expect to find food within the bladder. In entering they have to press upon the valve and push it back. As soon as they stop pressing upon the valve, the elastic character of the valve causes it to close by bringing it back on the under-lip cushion. The entrapped animals struggle to escape by pressing themselves against the valve, but their efforts are in vain, for it is impos-

sible for the prisoners to force the valve outwardly over the cushion, and they die in time either from starvation or suffocation. Their bodies decompose and the water-soluble products of decay are absorbed by quadrifid cells lining the entire inner wall of the bladder.

The Butterworts.

The butterworts comprise an interesting group of flesh-eating plants which are placed in the genus *Pinguicula*. About forty species exist, of which probably the best-known is *Pinguicula vulgaris,* a member of the *Utriculariaceæ,* which occurs in bogs or other damp places generally in mountainous districts of Northern North America and Europe. Each plant exhibits a root system of from about
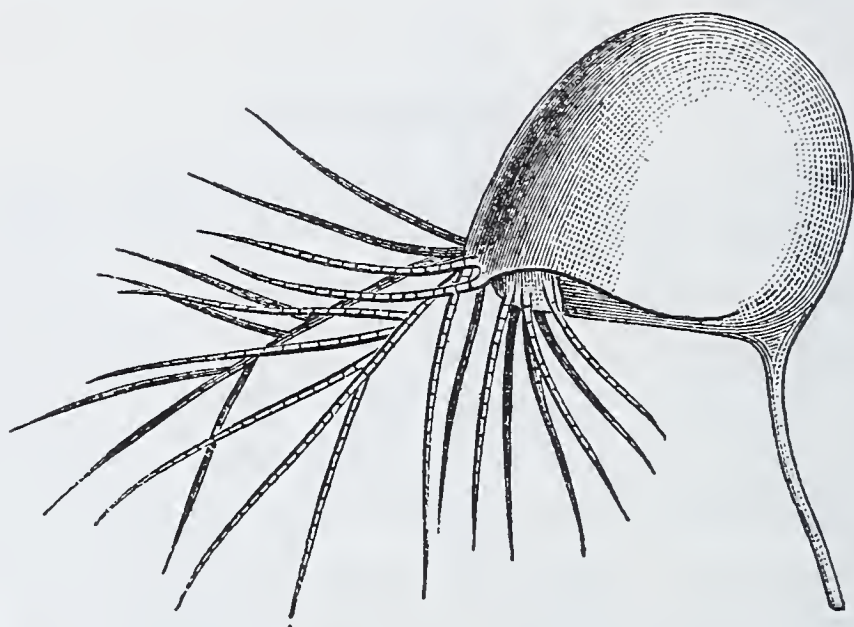
Fig. 10. *Utricularia neglecta.* Enlarged view of bladder-like trap.

five to sixteen short, submerged, unbranched roots, from which arises a rosette of oblong-ovate, yellowish-green leaves, the younger central ones being concave and more or less erect, the older marginal ones being flat or convex, with their lower surfaces resting upon the moist ground. From the center of the leaf rosette there arises a slender scape bearing a single flower of violet blue hue that is spurred in its corolla portion.

Alike with other investigated species of *Pinguicula,* the leaves of this plant have somewhat upturned margins, which give them the form of a broad trough, the upper surface of which is covered with a viscid secretion. Microscopical examination of this surface discloses two types of glands (excepting along the margin), the first being of toadstool shape and consisting of a cylindrical stalk bearing

a disc-shaped head of eight to sixteen cells arranged radially, the second consisting of a shorter stalk bearing an eight-celled head.

Darwin [15] and others have experimented with the leaves on living plants of several butterworts and found that drops of water, gum or sugar, and scratching of the surface of these leaves, produced no response, that insoluble solid bodies such as grains of sand and powdered glass allowed to remain for some time caused slight incurving of the margins and a slight increase in the quantity of mucilage by the glands, but that when nitrogenous bodies such as bits of cartilage, meat, clotted blood, *etc.,* are placed near the margin in contact with the glands they are excited and pour forth abundant
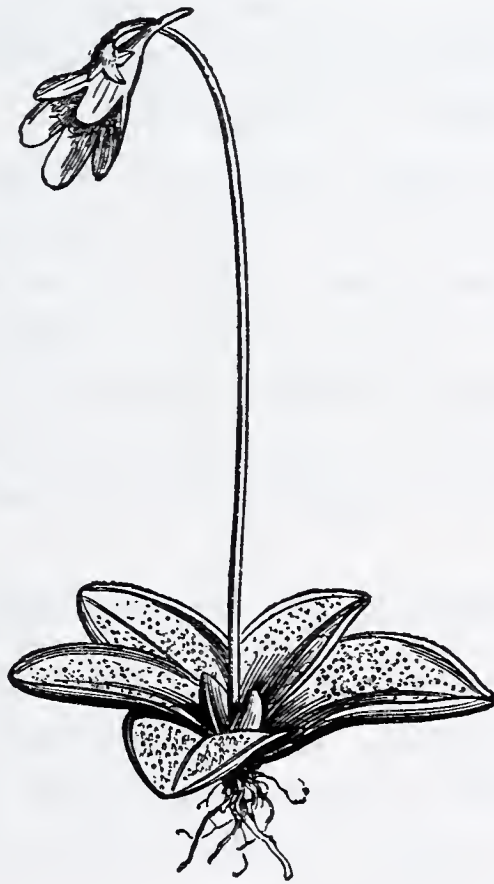
Fig. 11. *Pinguicula vulgaris,* a butterwort.

mucilage and an acid secretion. Moreover, prolonged contact with these bodies caused a marked incurving of the margin, which pushed them slowly toward the middle of the leaf, where more glands are present and so increased secretion. This acid secretion completely dissolved these substances, which were later absorbed by the leaf.

An idea of the time necesary for the secretion of fluid and the digestion and absorption of nitrogenous bodies by these leaves may be gained by the experiment of Darwin with three small cubes of tough cartilage from the leg-bone of a sheep (see *Insectivorous Plants,* by Charles Darwin, p. 382, 1884).

"Within ten hours and thirty minutes some acid secretion was evident, but the cartilage was little or not at all affected; after twenty-four hours the cubes were rounded and considerably reduced in size; after thirty-two hours they were softened to the center and one was liquefied; after forty-eight hours a trace of only one of these was evident and after eighty-two hours all three cubes were liquefied, the secretion was entirely absorbed and the glands were left dry."

When small insects alight from the air upon the leaf of the butterwort they become fastened by the mucilage and in struggling to extricate themselves only become deeper enmeshed by it. Within a short time the acid juice, secreted by the glands as a result of the stimuli, digests their bodies and all excepting their hard, indigestible, outer skeleta (exo-skeleta) is absorbed.

If small creeping insects come upon the margin of the leaf they stimulate the edge to curl over and the marginal glands to secrete. While the insect is enmeshed within the adhesive mucilage, it is slowly pushed by the curling up of the edges into the middle of the leaf, where the acid-secretion glands are most abundant. In about twenty-four hours the softer parts of its body are digested and absorbed and the leaf expands to its normal condition.

Significance of the Carnivorous Habit.

In all of the animal-eating plants which have been investigated structurally and chemically, sufficient evidence has been recorded to warrant the conclusion that these forms have developed their peculiar habit and correlated structure with the object of providing adequately for their nutrition.

Figures 3, 4, 5 and 7 are reprinted by the courtesy of the *Journal of the Franklin Institute* from papers by Hepburn, St. John and Jones.

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EXPLOSIVES AND EXPLOSIONS.

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To many persons, explosives mean only materials employed in war, but for many years these substances have been of great service in the arts of peace, especially the modern high explosives. Originally, the engineer was the person who operated war engines, which in ancient times were mostly mechanical contrivances for throwing stones or darts. Later, when building, road construction and other public works became the care of trained men, the "civil" engineer was employed. Ancient warfare had some facilities for destructive action by means of fire, and a book that dates from about the eighth century, though probably the original text is older, describes many methods of making burning projectiles. It is entitled "The Book of Fires to burn Enemies," and is said to have been written by "Marcus, the Greek."

The early history of mankind is but little known to us, but we recognize that warfare was soon developed. Our word "toxicology," derived from a Greek word meaning "bow," refers to that weapon, but especially the poisoned arrow used with it. The display of the rainbow was interpreted by the ancient Jews as evidence that the Deity had ceased warfare against humanity, for he had hung up his bow. The primitive man, who has left no written record, but a considerable amount of pictures and pottery, had very simple weapons, such as the stone, dart, spear, arrow, and, in historic times, at least, the sling-shot and later the more powerful mechanical engines. Of the engines that were employed in the pre-Christian centuries no definite material remains, but some descriptions of ancient writers indicate that stone- and dart-throwing apparatus and the battering-ram were much used. At the siege of Jerusalem by Titus, about 70 A. D., a stone-throwing apparatus of considerable power was employed by the Romans, a stone weighing about a hundred pounds being thrown four hundred yards. The low trajectory and velocity enabled the watchers to see it and they would call out, "Here comes the stone," and the defenders would rush to cover. The Romans painted the stone a dull color to make it less conspicuous, and thus may be said to have inaugurated *camouflage*. Greek fire, that is, the materials described in the book above mentioned, and probably similar materials, were used more

or less. Ancient battles, however, were practically noiseless, except for the shouting of combatants.

The date of the invention of gunpowder is uncertain, nor is it clear as to who was the originator. The Chinese appear to have had a gunpowder made essentially as our present product for centuries before Europeans used it. It is known that firearms employing gunpowder were used at the battle of Cressy in 1346, but there are indications of even earlier use. Standard gunpowder is a mixture of potassium nitrate, sulphur and charcoal, but some forms used for mining operations contain sodium nitrate. For many years the standard powder was all that was available for warfare or for blasting. In the earliest use in war, the charge in the gun was ignited by a slow match, later the flintlock was introduced, and finally the percussion cap. The latter method has been perfected so that the material which starts the powder (termed the initiator) is placed in the back of the cartridge, and fired by a piercing needle or some similar device.

The modern high explosives mostly use the oxidizing effect of the nitrates or allied compounds, but differ from gunpowder in being essentially one compound and not a mixture, although mixtures are often used. The earliest important high explosive of this modern type is guncotton, obtained by immersing common cotton, carefully cleaned and dried, in a mixture of strong sulphuric and nitric acids. The procedure requires care, and by varying the acid strength and other conditions, different grades of explosive can be obtained. Some forms are soluble in a mixture of ether and alcohol. These are rather less explosive and are largely used in the manufacture of collodion. The higher explosive forms can be exploded while somewhat wet, and such a mixture was used a good deal a few years ago. Many other substances analogous to cotton, such as starch, sugar and wood fiber, can be "nitrated" and produce explosives. An important step was made when glycerol was employed. The product "nitroglycerin" is a very high explosive and has found extensive use in engineering operations. It is a liquid, but by mixing it with finely powdered inert material, such as diatomaceous earth or even paper pulp, a safer product is obtained. This is called "dynamite" and is one of the best-known explosives. In later years other substances of this class have come to the front. Picric acid, which is a derivative of the action of nitric acid on phenol, was for many years not regarded as an explosive. It was

manufactured for dyers, having the property of dyeing silk and wool a fast, brilliant yellow. An accident that happened in England showed that under certain circumstances it will explode with great violence, and it was used in the Boer war under the name of "Lyddite." It has, however, some acid properties and corrodes the cannon. In the last war, trinitrotoluene, commonly called T. N. T., was used. This is closely analogous to picric acid, but is not acid and, therefore, not so corrosive. Upon the basis on which these few explosives have been produced, many other articles have been made, so that the literature of explosives is now very extensive and in the hands of specialists. Outside of these lines, a number of other very high explosives are known, but they are mostly so uncertain in their action that they have no practical value. By the action of strong ammonia water upon iodin, a brownish-black powder is obtained, which while moist shows but little sensitiveness, but when quite dry will explode violently on the slightest touch. It is obvious that such substances have no practical value.

Explosives have to be adapted to the purposes for which they are used. Two such purposes are especially noticeable. The projection of a ball or shell involves a somewhat different quality from that of the bursting or rending material. The explosive that throws the shell is not of exactly the same nature as that which bursts it. In recent years another type of chemical has come into extended use, namely, the asphyxiating projectile, but this is not an explosive form and need not be discussed here.

Explosions of great violence may be caused by many substances that are in themselves entirely incapable of such action. Among these are gases and finely divided combustible substances, such as coal, flour, starch and smoke particles. Modern industrial conditions have been seriously complicated by the liability of finely-divided material and the vapors of commonly used liquids to be the cause of severe explosions under comparatively slight influences. Occasionally the violence of the explosion is far beyond what would be expected from the general nature of the material. In some investigations by the Bureau of Mines finely powdered starch was tried, and the explosion was of unprecedented violence. The experimenters, who regarded themselves as at a safe distance, judging by experiments with coal dust, narrowly escaped serious injury. An explosion occurred in a room in which aluminum ware was being polished. The air contained fine aluminum dust and this was ignited

(apparently) by an electric spark from a defective connection. Much damage was done. Flour mills have been exploded with complete destruction by accidental ignition of flour dust. In all these cases the effect is due to the admixture of the combustible material with air. Alone, the material burns only slowly at most, and sometimes does not support its own combustion, but mixed with a large volume of air the combustion proceeds with great rapidity, a large volume of highly heated gas is produced and this causes what is termed explosion. The noise of an explosion is probably due to crash of the masses of air that have been separated by the expansion as they return to their original position.

The entire field of explosion and explosives has been very thoroughly studied, not only by scientists solely interested in the nature of the phenomena, but also by the great companies which manufacture explosives, and by the governments that are interested from the point of view of war. In the early part of the late war the Germans made air raids on London, in which much damage was done. For part of the time the material used was "thermit," an industrial product consisting of ferric oxide and aluminum, both in fine powder and intimately mixed. When ignited, this mixture burns with great heat, but no appreciable explosion. The object of the use of this material was to damage machinery and war apparatus. Thermit is used largely in welding operations. When ignited in contact with the closely approximated parts of a broken shaft, for instance, it promptly and completely welds the two. Therefore, if ignited in contact with any piece of machinery or a cannon, it will so block the parts it touches that they will be useless. It has to be fired by a special igniting mixture. This is, indeed, true of most explosives and highly combustible mixtures, and the study of these "initiators" or "primers" constitutes an important part of the science of this subject.

An interesting experiment may be made by heating ammonium dichromate. This is a crystalline compound having the composition $(NH_4)_2Cr_2O_7$. It is entirely permanent at ordinary temperatures, but when heated it soon produces a flame and liberates gases and a green powder. The products are essentially chromic oxide, nitrogen and water. As water is an easily condensible gas and chromic oxide is a solid, the products do not occupy much space, so that although the substance is of the nature of an explosive, its decomposition is attended by no danger, and by its means we can see what goes on

in the closed chamber of a gun when a high explosive is fired. Several substances are known that theoretically may be considered explosives, yet they do not act so under ordinary conditions. Ammonium nitrate, NH_4NO_3, has the composition of an explosive, for it can yield nitrous oxide and water, but when heated gently even in comparatively large masses it decomposes quietly with the production of these substances. Yet it may be that if a proper initiator can be found a more violent decomposition might occur. An example of such an action is noted above in the case of picric acid. A very destructive explosion occurred somewhat over a year ago at the nitrogen-fixation plant at Oppau, Germany. No definite explanation of the accident has been published. It is possible that the German chemists in charge know the details, but if so they have not disclosed them. It. is, however, not impossible that they have not been able to determine the cause. The destruction was so extensive and thorough that no evidence may be left to indicate the condition immediately preceding the accident. Some of the high explosives produce effects which cannot be explained on the ordinary principle, namely, that a large volume of gas is suddenly formed. A few grains of sulphur and potassium chlorate rubbed strongly in a wedgewood mortar will generally produce a loud noise, usually without appreciable action otherwise, but occasionally the mortar will be broken. In such instances, there is no action like the bursting of a shell; the fragments are not projected, and if, as usual, the experimenter is holding the mortar in the hand, no effect is noticed, except a slight stinging. Many other examples of these more eccentric explosives might be given.

Certain forms of guncotton, not as highly explosive as those used in war and blasting, have been long in familiar use. They are more or less dangerous, but rather from their rapid combustibility than from any real explosive qualities. Collars, cuffs and many toilet articles are made from this "low nitrated" cotton, mixed with other substances. The most familiar form is probably the standard motion-picture film. This is inflammable and burns with much vigor, so that such films are not permitted to be shown except under careful protection against fire and panic. The less explosive forms of guncotton are often called "negative cotton," on account of being used in the early days of photography for making the coating on the negative plate in which the sensitive silver salt was held. A solution of this kind of guncotton in ether and alcohol is known as collodion.

Efforts have been made, and are still in active progress, to obtain a film less combustible. At present one form of film is in the market made by means of acetic acid. It is a cellulose acetate, just as the more combustible products are cellulose nitrates. This acetate film is commonly known in the trade as "non-flam," but it is not wholly non-inflammable. It burns very slowly and does not readily maintain its own combustion. It is somewhat weaker than the standard film and this has interfered with its use by the motion-picture industry. It is used in special size in apparatus adapted only to that size for general exhibition, as the insurance authorities do not require a booth or other fire-fighting devices.

The problem of the use of explosives in war has become very serious in recent years because the means of offense are much more effective than means of defense. Submarines and airplanes render armored ships and fortifications of little value. In addition to the ease with which large quantities of high explosives may be thrown on both military establishments and residential districts, poisonous gases are also available. It is thought by many experts that the next war between any of the great nations will be largely fought in the air. At present there is an enormous development of commercial air service. These machines can be easily and quickly turned into bomb-throwing forms, and the ravages of war extended over the whole of a noncombatant area. Intimately connected with the production of modern high explosives and poisonous gases are the industries based upon coal tar. These have grown up principally in connection with the manufacture of dyestuffs, but the manufacture of most of the high explosives is carried out by an extension of the methods of making what are called the "intermediates," that is, the substances which, though not in themselves colored, produce the colors by being mixed under special conditions. This, which is known as "assembling," is a large part of the work of the dyemaker. Germany for many years was the leader in both the theory and practice of these procedures, and the late war showed how such leadership gave power to the nation that possessed it. Germany is waiting for revenge—Germans, indeed, would not be human if they did not cherish such hope—and it behooves the Allies and Associated Powers who won the war to develop even at some sacrifice a complete system of manufacture both of coal-tar and nitrogen-fixation products.

THE MAKING OF MEDICINES.

By E. Fullerton Cook.

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Pharmacy and Science.

It is not possible to give consideration to the development of
medicines and that of which it is but a minor phase, namely the
effort through the ages to relieve humanity from the ravages of
disease, without becoming impressed by the spirit of sympathy and
the desire to help others, which is the dominant force in the develop-
ment of the science.

True, the quack, the impostor and the charlatan have always
been ready to take advantage of the credulity and need of the sick
and will probably continue to exploit those in need until checked
by law, but to the honor of those who have gradually perfected the
various divisions of the medical arts, history records their nobility
of purpose, their untiring and unselfish search for cause and cure
and the altruism of their lives of service.

Medicines of Primitive Man.

While there is no record carved in stone or handed down in
precious parchment to prove the first use of medicines, yet the
customs among primitive people, recorded by travelers of our own
time, would seem to prove that wherever men and women have
lived, they have discovered simple remedies among the growing
plants about them. Undoubtedly, the first medicines were herbs,
the virtues of which were probably discovered by observing their
instinctive use by animals or by actually trying their effect upon
themselves or others. In African tribes today and elsewhere that
the modern medical sciences have not found their way, the "medi-
cine man" still concocts strange mixtures from herbs and other
materials, often of a gruesome or offensive character, yet of sup-
posed magic power, and he administers these to the sick, usually
accompanied by elaborate ceremonies and mystic rites, presumably
to add efficacy to the cure.

From the earliest dawn of history, the records show that man
believed sickness to be caused by an evil or malignant spirit and
thus entered the religious phase into almost every early attempt to
cure the sick.

By empiric methods, that is, by the actual trying out of the

effects of various herbs, seeds, roots or other portions of growing plants, often no doubt in teas or decoctions, or the administration of the earths, minerals and metals as they were discovered, there was gradually built up a superficial knowledge of the effects of these upon the body. It was observed that some decoctions would cause emesis or vomiting, others have cathartic action, another would produce diaphoresis or perspiring, while still others were toxic and could cause death as a poison.

About these empiric observations, and the religion of the nations, grew up the schools of medicine, and always there was introduced much superstition and supposed occult power as contributory to the cure.

IMHOTEP.

From "The Evolution of Modern Medicine," Osler.
Courtesy Yale University Press.

Probably the earliest written records are those of some sixty centuries ago, when from the oblivion of unknown ages there arose on the bands of the Nile a great civilization.

The fame and ability of a physician of this period, named Imhotep, has been preserved through the centuries. His priestly wisdom, magic, ability to formulate wise proverbs, and knowledge of medicine and architecture, gradually established him, in tradition, as a god, and twenty-five hundred years later the Greeks referred to him as synonymous with their own Æsculapius.

In the practice of medicine as developed in Egypt, each physi-
cian, who was always a priest, was permitted to practise only his
specialty. There were those who treated only the eye, or the
teeth, or head or stomach, and they were paid by the government,
although fees were also permitted.

A PAGE FROM THE "PAPYRUS EBERS."

From "The Evolution of Modern Medicine," Osler.
Courtesy Yale University Press.

Through the discovery of the Papyrus Ebers in 1872, which is
supposed to have been a collection of formulas of about 1552 B. C.
(corresponding to about the twenty-first year of the life of Moses),
it is possible to know something of the art of the apothecary of
this early period. The remedies used are chiefly herbs, but include
lizards' blood, teeth of swine, putrid meat and fat, excreta and other
disgusting substances. Among the remedies named are oil, wine,
beer, yeast, vinegar, turpentine, figs, pomegranate bark, myrrh, mas-
tic, frankincense, opium, wormwood, aloes, peppermint, cassia, car-
away, saffron, linseed, juniper berries, henbane and also some inor-
ganic substances, including iron, lead, magnesia, lime, soda, nitre,
vermilion and sulphur. Some of these, of course, have only been
guessed at and many other names are given which have not been
identified.

Many formulas are simple but others very complex, a poultice, for instance, containing thirty-five ingredients.

A purge was to be made by, boiling together one part of milk, and two parts each of honey and yeast. Pills were to be made from equal parts of honey, absinth powder and onion. For the falling of hair, apply a mixture of fats obtained from the horse, the hippopotamus, the crocodile, the cat, the snake and the ibex.

These few formulas will illustrate the materia medica of the day and the problems before the pharmacist if he were to meet the demand of the Egyptian physician.

The contemporary Assyrian and Babylonian medicine consisted chiefly of religious incantations intended to drive away the "demons" believed to be responsible for sickness, but also accompanied by the administration of remedies, of which many were in common use.

The Babylonian physician-priest believed that the liver was the centre of life, mind and soul, having observed its size, position and richness in blood in sacrificial animals, and for many centuries this belief was maintained. They also introduced astrology and thought that the heavenly bodies influenced human welfare.

Hebrew Medicine.

There is little evidence in Jewish literature that medicines in the sense in which we now know them, were used internally. The Pentateuch code provides for social hygiene of an advanced order, following many of the customs and teachings of both Egypt and Babylonia, but surpassing these in some respects. Many diseases were recognized, but the remedy usually depended upon was a miraculous cure through the power of the Lord.

In earlier translations of the Bible the "apothecary" is frequently referred to in the preparation of ointments and ceremonial oils, but in modern translations this is changed to "perfumer."

Many drugs are mentioned as Balm of Gilead, supposed to be the resinous exudation from Balsamum Gileadense. The "holy incense" consisted of equal parts of "stacte" (supposed to be myrrh), "onycha" (supposed to be a variety of sea-snail), galbnum and frankincense. This incense was used only for worship in the tabernacle and there was a severe penalty for imitating it. Olive oil was employed for annointing the hair and skin and the "holy annointing oil" contained myrrh, cinnamon, calamus, and cassia in definite proportions, steeped in olive oil. "Aloes" was used as a perfume, but it

was not the drug of today, but probably a perfumed wood from aquilaria agallocha, the eagle wood of India.

Wormwood, which produces a bitter flavor, also gall, were referred to by comparison, to indicate something disagreeable. Hyssop (not identified), juniper, nitre, mustard seed, vinegar, anise, saffron, pomegranate fruit, figs and spikenard are all mentioned but not as medicines, although a fig poultice, for Hezekiah's boil, is directed by Isaiah.

China and Japan.

In Chinese and Japanese medicine, for centuries, there were employed many charms and enchantments but also medicinal herbs, parts of animals, animal excretions, etc. The chief dependence for the cure of diseases was placed, however, upon soothsayers and exorcists, who danced in frantic or semi-delirious state, often horribly torturing themselves, that the evil spirits causing sickness might be driven away.

It is interesting to note, however, that the Chinese successfully practised inoculation for smallpox as early as the eleventh century.

European medicine found its way into Japan about 1770, but only within recent years has modern medicine been extensively introduced into China.

Greek Medicine.

Apollo was the legendary god of medicine among the Greeks, but his son, Æsculapius, losing his divine attributes, became the emblematic god of healing and with his staff and serpents appears today with many associations of medicine. He is supposed to have lived about 1250 B. C. His sons were also physicians and, according to legend, accompanied the Greek heroes at the siege of Troy. Æsculapius and two of his daughters, Hygeia, symbolic of Health, and Panacea, representing Medicine, were worshipped as gods by the Greeks and Romans for many centuries.

About 300 B. C. between 300 and 400 temples were to be found in Greece, dedicated to him and the healing art. In these temples, where priests presided, great attention was given to diet, exercise, massage, bathing, and, when necessary, drugs were given.

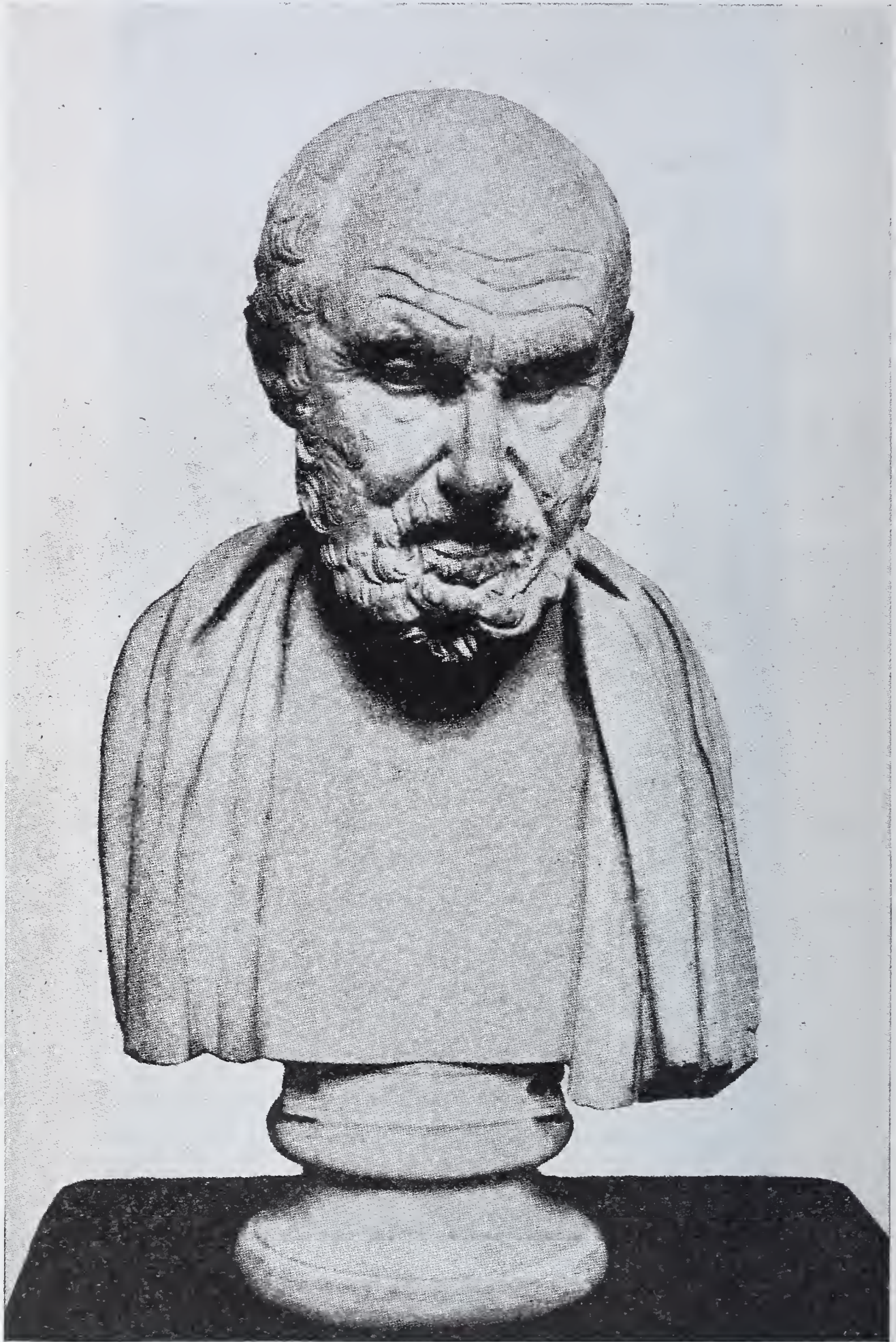The chief dependence was placed, however, upon the direct aid of the god, and for more than a thousand years the power of Æsculapius was supreme.

ÆSCULAPIUS.
From "The Evolution of Modern Medicine," Osler.
Courtesy Yale University Press.

The true founder of Greek medicine is recognized in Hippocrates, who was born 460 B. C.

Courtesy Yale University Press.
HIPPOCRATES.
From "The Evolution of Modern Medicine," Osler.

The writings attributed to Hippocrates are many, presumably copied from century to century. Naturally it is impossible to definitely separate the authentic from the spurious. The earliest known manuscript is from the ninth century.

The most important information about his writings and treatments came through Galen.

At least 400 substances (vegetable drugs, chemicals, etc.) were employed by Hippocrates and a list of these includes over 200 used in the modern drug shop. Among these are absintheum, althæa, alum, ammoniac, calamus, cardamon, chenopodium, cinnamon, clove, colocynth, coriander, elaterium, euphorbia, fennel, galls, garlic, hemlock, henbane, juniper, licorice, linseed, mercury, myrrh, nitre, oxygall, pennyroyal, pepper, pomegranate, poppy, lime, scammony, squill, stavesacre, sulphur, thyme, turpentine, verdigris and many others.

To Hippocrates is attributed the famous moral code, which has been the creed of physicians for twenty-five centuries.

He was also interested in pharmacy and Galen quotes him as saying, "We know the nature of medicaments and simples, and make many different preparations of them, some in one way, some in another, some simples must be gathered early, some late, some we dry, some we crush, some we cook," etc.

He made poultices, gargles, pessaries, pills, ointments, oils, cerates, eyewaters and inhalations. He is even supposed to have made tablets or lozenges in different shapes, one square from antimony, another triangular, each for a specific purpose.

The great name in Greek medicine following Hippocrates was Galen, born A. D. 130, and his name is also immortalized in pharmacy through its application to the general class of medicines known as "galenic preparations," including tinctures and wines of vegetable drugs, etc. It was during the period of his life that pharmacy was greatly developed, especially the art of compounding.

An illustration of a compound used for cholera, commended by Galen, is: Henbane seed, 2 drachms, Anise, 1 drachm, Opium, ½ drachm, made into 30 pills.

Another for coughs was 4 drachms each of the Juice of Hemlock, Juice of Henbane, Castoreum, White Pepper, and Costus, and 1 drachm each of Myrrh and Opium.

The medical practice, up to the beginning of the sixteenth century, was largely that taught in this Greek School.

The practice of pharmacy, however, was extensively developed during this period, especially by the Arabs.

The work on chemistry, attributed to Geber and his associates in the eighth century, stands as a monument to the Arabian genius.

To the pharmacy of the Arabian School is credited the development of the use of alcohol as a solvent. They introduced sugar, syrup, rhubarb, senna, camphor, manna, musk, nutmegs, tamarinds and other drugs. They first distilled rose water and first established pharmacies as separate from the physician's office, thus giving to pharmacy a new dignity.

Paracelsus, early in the sixteenth century, was the first to materially add to the Hippocratic-Galenic School of Medicine. He made many important chemical studies, discovering zinc, a number of compounds of mercury, including calomel, also flowers of sulphur, and urged the use of preparations of iron and antimony.

Perhaps his greatest reputation was due to the introduction of tincture of opium (laudanum) with which he seemed to effect miraculous cures. His work stimulated important study in chemistry and pharmacy, and little by little, through the succeeding centuries, the knowledge of drugs and their uses increased and the foundation was laid for the tremendous advance of the last fifty years.

Gradually superstition and the belief in the miraculous power of certain medicines has been swept aside.

Several of these older remedies have enjoyed a reputation covering many centuries and several were considered essential for the practice of medicine, even up to the eighteenth century.

Four of the most important were Mithridatum, Venice Treacle or Theriaca, Philonium and Diascordium. Galen gives the formulas. That of Theriaca was supposed to have originated with Nero's physician, Andromachus.

Mithridatica contained 47 and Theriaca 62 ingredients, modified formulas for the two preparations being found as late as 1746 in the "London Pharmacopœia."

Philonium was really a confection of opium, but contained many other ingredients. It was used for colic and in modified form remained in the "London Pharmacopœia" until 1867.

Diascordium, used as a preventive of plague, was accredited to Frascatorius and continued to be used during the eighteenth century, becoming a popular household opiate.

It is interesting to note that these four preparations all con-

PARACELSUS.

From "The Evolution of Modern Medicine," Osler.
Courtesy Yale University Press.

tained opium. For centuries Theriaca or Treacle was made almost exclusively in Venice, but in 1585 the apothecary to the English Queen claimed that he was able to produce a product equal to that made in Venice or Constantinople.

The antiquity of some medicines used today is shown by the dates of their origin.

"Black Draught" (Compound Infusion of Senna) was originated about 1600 by an Italian physician, Mannogetta.

Blaud's Pills—Proposed by Dr. I. Blaud in 1831.

Citrine Ointment (Mercuric Nitrate) first noted in the "Edinburgh Pharmacopœia" about 1722.

Cold Cream—Attributed to Galen.

Diachylon Plaster (Lead Plaster).

The formula was originated by a physician of the Caesars, Tiberius Claudius Menecrates.

Dover's Powder (Powder of Opium and Ipecac) was originated by Dr. Thomas Dover, born in 1660.

Fowler's Solution of Arsenic—Published by Dr. Thomas Fowler in 1786.

Gregory's Powder (Comp. Powder of Rhubarb) was frequently used by Dr. James Gregory, who died in 1822.

Hiera Picra was sold in Rome and Alexandria 2000 years ago and is yet in the "National Formulary" as Powder of Aloes and Canella.

Paregoric—Originated by Le Mont at the University of Leyden in 1702.

Plummer's Pills (Pills of Antimony)—The formula published by Dr. Plummer in 1751.

The Medicines of Today.

During the latter part of the nineteenth century and in the past two decades, the inherited beliefs and the empiric evidence in the potency of the medicines of our fathers have been subjected to careful scientific study and test.

Some failed to prove their therapeutic value and have been abandoned. A few, at first condemned, were later found, through newly discovered methods, to fully justify the faith and clinical evidence of the older physicians. Cod liver oil is a striking illustration of this group, the recent vitamine discoveries having scientifically demonstrated a basis for its value.

The searching analysis of the twentieth-century seeker for truth has found in other older remedies the vital principles which possessed definite and dependable physiologic action. In such medicines an earnest effort has been made to provide forms for administration which will be reliable—which will always produce a specific action and, so far as possible, in the same degree.

This has meant the manufacture and further purification of many well-known chemicals, that they may conform to established standards and contain no foreign or deleterious impurities. It has also required the development of ingenious methods for determining the amount of active constituents which were found to exist in some vegetable and animal drugs and also the separation and purification of some of these constituents for separate administration, as illustrated by quinine, the alkaloid for cinchona bark and epinephrine from suprarenal glands.

In other cases, when drugs were known to produce definite action upon the human body and upon animals, but no constituent could be separated chemically to represent that power, it was necessary to devise other methods of assay, involving a study of their action upon animals, that preparations might have uniform and assured physiologic activity.

Thus has the scientist in the pharmaceutical field, with his modernly equipped laboratory, and numerous original investigations, provided preparations of the older remedies which are more dependable and possess greater uniformity of action than was formerly possible.

New methods of administration have also been devised both for convenience and greater efficiency.

Medicines in capsules and tablet form have gained great popularity, largely because of convenience, and the preparation of medicinal agents in sterile solution or mixtures, dispensed in ampuls, for intramuscular or intravenous injection, have been found by many physicians to be the more efficient method of drug administration.

In addition to improvements in the quality and reliability of the older remedies and in the methods of their administration, the search for new medicines, especially specifics, has been conducted untiringly by research workers throughout the world and has resulted in the development and introduction of hundreds of new remedies.

In the field of Organic Chemistry, the so-called "Coal-Tar Synthetics" were among the first to prove their value as medicines. Many of these products were developed in research laboratories abroad and were exploited commercially with enormous profit to those who controlled the process patents or trade-marks. The natural result of this condition was a tremendous stimulation in research and also the exploiting of many products of little or no value and even the introduction of dangerous or habit-forming drugs.

Out of this maze of "Newer Remedies" a few have survived the acid-test of time, among them antipyrine, phenacetine, acetyl-salicylic acid (aspirin), atophan, all now official, and many others, some of which are spoken of more in detail in the following summary:

Hypnotics.

Early in the study of synthetic remedies, substances were discovered which induced sleep without apparently possessing the habit-forming and other objectionable characteristics incident to the use of opium. Trional and sulphonal were long used and are now official. Other products are also now largely employed, as barbital or veronal, barbital-sodium, luminal and luminal-sodium.

Another group of hypnotics is represented by the official hydrated chloral and also by a number of synthetic chloral compounds, for which special advantages are claimed. Among these are butyl-chloral hydrate, chloralformamide, and chlorbutanol.

Arsenic Compounds.

In the search for specifics for well-defined diseases, it had been demonstrated that arsenic in certain organic combination could be given in doses which would kill organisms of the protzoa type and yet remain non-toxic to the human body.

A number of combinations of this character had been developed, including sodium cacodylate, but it remained for Ehrlich to produce Salvarsan and Neosalvarsan, well-known in this country as Arsphenamine and Neoarsphenamine, which have proven of inestimable value in the treatment of syphilis, and have been employed successfully in other spirillum affections, such as relapsing fever and malaria.

Anesthetics.

The importance of the discovery of Ether and Choroform, whereby painless operations were made possible, cannot be over-

estimated. Much of the development of modern surgery was made possible through their use.

Other general anesthetics have been introduced, such as ethyl bromide, but ether is still most generally employed.

It has been found possible to use a local anesthetic in minor operations and for this purpose the alkaloid cocaine was long used.

Many synthetic products are now being offered, however, under trade-marked names, various advantages being claimed, such as their being non-habit-forming, or less toxic, etc. In this group may be mentioned butyn, novocain, procaine, holocaine, stovaine, benzocaine, apothesine, and many others.

Tannin Combinations.

Tannin compounds which will not dissolve in the stomach as would tannic acid, but which will liberate tannic acid in the intestines, used chiefly for the treatment of diarrhœa, are among the developments of the modern research laboratory.

In this group are found acetannin, albutannin, protannin, etc.

Antiseptics.

The exigencies of the great war required more efficient antiseptics than those available and there were developed a better technique in the treatment of wounds, more effective forms for well-known antiseptics and also new and more powerful products.

In the latter group, certain substances closely related to the coal-tar dyes were found to possess powerful germicidal action. Those which have been most effectively used are known as acriflavine and proflavine.

Of the older antiseptics, chlorine was made available in non-irritating form, largely through the extensive researches of Carrel and Dakin. The so-called Carrel-Dakin Solution, a slightly alkaline solution of chlorinated soda, containing from 0.38 to 0.48 per cent. of available chlorine and the later chlorine-liberating products known as "chloramine-T" and "dichloramine-T," used as antiseptics or wound treatment, were notable developments of the war. The product halazone, for the purification of drinking water, also proved to be of great value.

Mercury bichloride has been for many years the standard antiseptic and germicide, but other less irritating compounds of mercury have also been developed, such as mercurochrome, mercurol, mercuric benzoate, mercuric cyanide, mercuric oxycyanide, mercuric salicylate, mercuric succinimide, etc.

Silver nitrate, also one of the older germicides, was always limited in its use because of its caustic action. Organic combinations of silver have been developed, however, which possess special merit as antiseptics, without being caustics. Among these are protargol, argyrol, cargentos, collargol, etc.

Urinary Antiseptics.

One of the developments of the synthetic laboratory has been the valuable urinary antiseptic hexamethylamine, in which the well-known antiseptic action of formaldehyde is made available by an organic combination, which permits its administration without irritation. Decomposition and the liberation of formaldehyde occurs during its secretion, if the urine is acid.

Animal Products.

The *bile salts,* sodium glycocholate and sodium taurocholate, and also the purified extract of ox-bile, have maintained a definite place in modern medicine as a stimulant to the activities of the liver. Highly purified products, suitable for administration by the mouth or for injection, have been developed by the modern pharmacist.

The digestive ferments, consisting of the active digestive enzymes, pepsin, amylopsin, trypsin, etc., separated from the stomach or pancreas of the hog, have found a useful place in modern medicine and are available in concentrated and highly purified form.

The so-called *"ductless glands"* have recently assumed an important place in medicinal treatment.

The action principle of the suprarenal gland, known as epinephrine, has fully established itself and now the active principle of the thyroid gland, known as thyroxin, is also available.

The dried thyroid and pituitary glands have also found a definite place in the materia medica and study is being made of ovarian substance, the parathyroid gland and others.

Blood Clotting.

This phenomenon, familiar to all, is due to a ferment, known as "thrombin," normally present, acting upon the fibrinogen of the blood. Substances which stimulate this action, useful in hemorrhages, have been prepared from the brain of cattle and are sold as brain lipoid, thromboplastin, kephalin, etc.

Serums and Vaccines.

This group of biologic products probably stands at the peak of modern achievement in the fight to conquer disease.

Diphtheria antitoxin occupies the foremost place, since its introduction and development has made it possible to control and often prevent that dread child disease. Antitetanic serum has also proved its efficiency, especially as a preventative of tetanus and, probably saved more lives during the war than all that were lost. Many other serums are being used and their value and new application is constantly being extended. Among these are antianthrax, antidysenteric, antigonococcus, antimeningoccus, antipneumococcus, antistreptococcus, etc.

In addition to these substances, which produce active immunity, that is, in themselves neutralize the toxic poisons from disease, there are others which stimulate the development of antitoxins, within the body of the patient. This is known as "passive immunity."

The best-known of this group is vaccine virus to prevent small-pox.

The effectiveness of this treatment in the prevention of small-pox has been so fully demonstrated that, by the law of all civilized countries of the world, every man, woman and child must be "vaccinated."

Other substances of the passive immunity type, known as bacterial vaccines, are also extensively used. The best known is probably the typhoid vaccine, which is credited with having almost eliminated that former dread disease from our army camps. Vaccines are also used for the treatment of many other diseases caused by bacterial agents, such as the gonococcus, meningococcus, pertussis (whooping cough), plague, pneumococcus, staphylococcus, streptococcus, etc.

Proteins.

In recent years it has been discovered that the cause of hay fever, asthma and other systematic disturbances are the result of irritation from various protein substances. These are frequently the pollen of plants, but it has been shown that some persons are sensitive to many other forms of protein which may be found floating in the air or taken as foods.

Solutions of various proteins are being employed as diagnostic

reagents, as the patient can often avoid contact with the protein substance when the specific cause of irritation is determined.

Solutions of soluble constituents from these proteins are also being injected for the purpose of developing immunity.

Leprosy and Chaulmoogra Oil.

The heroic searchers for the cause and treatment of the dread disease "leprosy" have at last discovered a remedy which has cured many cases and at last promises hope that the world may be freed from this scourge. Chaulmoogra oil was first used, but the research worker has found that the active ingredients can be prepared as the ethyl esters of the fatty accids of the oil, and that in this form the remedy may be used hypodermically and much more effectively.

Radium.

This summary of modern medicines would not be complete without mention of the marvelous element "radium," the rays of which are now so extensively employed in the treatment of pathogenic tissues.

It is marketed today largely in the form of its salts, the bromide, carbonate, chloride and sulphate.

The number of "Newer Remedies" which have been introduced to the medical profession during the last two decades is almost legion. Only a limited number have survived and of these but a few representatives have been named to illustrate their varied character.

While now and again a remedy will be exploited with but little consideration other than the financial return, this is less and less true. Research only a few years ago was largely conducted by commercial houses who were compelled to reimburse themselves for the enormous cost of research by selling the product. Today many other groups are conducting research, often under large endowment, and a better condition has developed in which such products are being marketed by commercial houses, under license, but the control still retained by the research organization, the license being granted to more than one manufacturer and distributor.

Two recent products so controlled are thyroxin, the active principle from the thyroid gland, developed at the University of Minnesota and licensed for manufacture and sale to a commercial house. Another is the much-talked of "insulin," for the treatment of diabetes, developed at the University of Toronto and being similarly marketed.

In presenting this summary of the medicines of our forefathers and of today for a popular evening talk, the treatment has been necessarily brief, and far from complete. Many of the illustrations shown on the occasion, which it has not been possible to reproduce here, were supplied by manufacturing pharmaceutical and chemical firms and appreciation for their courtesy in supplying these is hereby expressed.

The historical slides were prepared for the occasion from old prints and illustrations collected from many sources. Other slides illustrated the modern cultivation of medicinal plants on a commercial scale, including cinchona forests, the manufacture of chemicals, pharmaceuticals and biologicals, including the extensive animal farms incident to serum and vaccine production, and pictures of huge stocks of chemicals, galenicals and serums, and of the extensive laboratories required to analyze the raw material and standardize the products were also elaborately illustrated. These latter pictures were supplied by Burroughs, Wellcome and Company, Johnson and Johnson, Powers, Weightman, Rosengarten Co., H. K. Mulford Co., Eli Lilly and Co., E. R. Squibb and Sons, Sharpe and Dohme and Parke, Davis and Co.

IRON AND IRON ALLOYS.

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Wrought iron and steel were known to the ancients; the tempering of steel also antedates exact history. Cast iron became known at a much later period, when the increased manufacture of iron finally led to the construction of the blast furnace, in which the heat of reaction of large quantities of iron and the presence of excess of carbon gave a liquid mass which could be cast. The first construction of any size in England was a bridge built in 1788. The immense development of the iron and steel industry began in 1856 with the manufacture of Bessemer steel.

"The total value of all mineral products in the United States in 1913, the last normal year before the World War, was approximately $2,500,000,000. Of this, a little more than one-third, or $883,000,000, was for metallic products of which almost exactly one-half is due to pig iron. The United States produces far more iron and steel than any other nation, her total output being fully 40 per cent. of the world's production."

Iron is undoubtedly the most important of the metals. Were all the gold of the world destroyed by magic, after the financial convulsion had adjusted itself to the loss of this measure of value and some new standard had been agreed upon, industry would move on at its usual speed. With iron similarly removed, industry would be pitifully helpless. There would be practically no tools or machines with which to work, and, worse still, nothing to make them with and little from which they could be made. The abundance of iron, the comparative ease with which it is obtained from its ore, its strength, and its adaptability are the chief reasons for the wonderfully important part it plays in human affairs. Of its adaptability Bradley Stoughton in "Rogers' Industrial Chemistry" says:

"Iron can be made either the strongest or one of the weakest of metals; either the most magnetic or one of the non-magnetic metals; one of the hardest or one of the softest; one of the toughest or one of the most brittle; it may have a coefficient of expansion which changes in atmospheric temperature varying almost from zero to a maximum, and it may be given a combination of some of

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these different properties at will, according to the purpose for which it is to be fitted in service. And most of these variations are brought about by changing the amount of foreign elements by less than 5 per cent. of the mass, or by giving it a different heat treatment, or by both together."

The most important chemical properties of iron from a practical standpoint are: First, its liability to oxidation in damp air (rusting); second, the ease with which its oxides (ores) are reduced at all temperatures above 500° F. (260° C.), and, third, its very powerful chemical affinity for carbon.

Its most important physical properties are its strength, magnetism and ability to become hardened and to retain a durable cutting edge after appropriate manufacture and treatment. In these three properties it can be made to excel all other known substances. Add to them its cheapness, and we can understand the importance of the ferrous metals to industry and civilization.

Ores.—The chief ores are the oxides, Fe_2O_3 and Fe_3O_4; the former occurs anhydrous in hematite (red) and hydrated in brown hematite and limonite. In only a few localities is the carbonate important. Unless the proportion of iron is at least 35 to 40 per cent., the ore cannot be smelted with profit, except where the cost of mining plus mechanical concentration is low.

Cast Iron.

Over 95 per cent. of all the iron ore treated goes into the blast furnace, where it is generally smelted with coke, an appropriate flux (usually limestone) and preheated air yielding a relatively impure grade of metal known as pig iron.

Because of its impurity and therefore its friability, pig iron cannot be worked or wrought. Many millions of tons per year are used in the form of castings, and the remainder purified. The purification consists in oxidizing the carbon, silicon and other impurities, thereby converting it into wrought iron and steel.

Malleable Cast Iron.—Iron castings lack strength and ductility on account of the impurities contained and more especially on account of the large flakes of graphite, which destroy the continuity of the metallic mass. On the other hand, steel castings are costly to make, not only because of the expense of the manufacture of

the steel, but chiefly because of the relative infusibility and high shrinkage on cooling. A between-product has therefore been developed to which the name of malleable "cast iron" has been given, because, although its composition approaches that of ordinary cast iron, it differs from it in having a limited amount of malleability. It also has greater strength than cast iron and a very moderate degree of ductility. Malleable cast iron is made by first making castings of white cast iron in which the carbon is usually under 3 per cent. and all in the combined form; these castings are then maintained at a bright red heat for two or three days or more, which results in the carbon being precipitated in very minute flakes of graphite, known as "temper carbon." Temper carbon differs from graphite chiefly in the small size of its particles, and the characteristics of malleable cast iron are due to this difference and also, in lower degree, to the circumstance that the amount of carbon and phosphorus is less.

Wrought Iron.

Wrought iron is produced by heating cast iron in a puddling furnace, lined with hematite to furnish oxygen, the flame from a fire at the side being led over the charge, which is wrought or worked during the process. At the end of about one and a half hours the carbon, silicon and manganese are almost entirely eliminated, as well as a portion of the phosphorus and sulphur. The iron is then drawn from the furnace in a pasty state, because the heat is no longer sufficient to maintain it in the liquid form in this purified condition. Wrought iron so produced is one of the purest of the iron-steel products. Its distinguishing characteristic is the webs and strings of slag mixed with it, which are drawn out by the hammering or rolling process, and give the metal its fibrous structure; on account of the freedom from carbon it lacks great strength and cannot be made to take a temper. Wrought iron is a term now little used, for it has in a large measure been replaced by soft steel, but there is still a demand for it for certain purposes.

Steel.

This form of iron may be made by a variety of processes, from either pig iron or wrought iron.

The immense development of the steel industry began in 1856, when the acid Bessemer process was perfected, in which the molten

cast iron is placed in an iron converter lined with some difficultly fusible material (siliceous), and a current of air turned on.

The complete purification of ten to twenty tons of liquid pig iron requires only seven to fifteen minutes. The heat produced by the oxidation of the impurities is sufficient not only to keep the bath in the liquid condition during the operation, but also to raise its temperature more than 575° F. (300° C.). The liquid metal, however, dissolves a good deal of iron oxide, which has a very harmful effect upon its qualities, but is nearly all removed by the addition of manganese at the end of the "blow." The appearance of the "converter" flame gives an index by which the operation may be followed and controlled. When the oxidation of impurities is completed, the flame shortens, or "drops," and the blowing is discontinued. Then is added a predetermined amount of manganese to remove absorbed oxygen; silicon to prevent gas bubbles or "blowholes," and carbon to give the desired degree of strength or hardness, or both. Bessemer steel is the lowest in price and poorest in quality, and in America this process is now rapidly giving way to the basic open-hearth process, chiefly because the supply of ore from which pig iron can be made, suitable for the Bessemer process, is yearly running lower. The great field of the Bessemer process has been in the manufacture of railroad rails, wire and pipe. For the two latter commodities it bids fair to retain its predominance for a time at least, because it is especially adapted to the manufacture of steel low in carbon.

Basic Bessemer.—Acid Bessemer slags are rich in silica, and this prevents the elimination of phosphorus from the metal, because silica will force phosphorus out of the slag unless there is a great predominance of basic radicals present to unite with both silica and phosphoric acid. By lining the converter with basic material, using pig iron low in silicon and using large quantities of lime, a basic slag is produced which retains the phosphorus. The success depends upon a high phosphorus content in the pig iron in order to supply the necessary heat.

Acid Open-Hearth.—The pig iron, to which some scrap steel or iron ore is generally added, is placed in a reverberatory furnace lined with siliceous material; the hot gases will burn out some of the impurities but will not remove phosphorus and sulphur. The process yields the best grades of structural steel and steel castings.

Basic Open-Hearth.—In this process the furnace is lined with magnesite or dolomite and the phosphorus, silicon, manganese and carbon are oxidized to as low a point as may be desired, the first three passing into the slag. An important, although somewhat uncertain, amount of sulphur is also carried into the slag as CaS. This steel is liable to contain dissolved oxide and also to be impregnated with gas bubbles or "blowholes." The process can be used with a number of ores containing phosphorus, which would not be available otherwise.

Duplex Process.—A combination of the acid Bessemer and basic open-hearth processes, of recent importance, enables rapidity of working and elimination of phosphorus. The pig iron is blown in the converter until the silicon and manganese and about half the carbon are eliminated, when it is transferred to the open-hearth furnace, where the remainder of the carbon and the phosphorus is oxidized.

Crucible Steel.—If wrought iron be heated with charcoal, pig iron or some other substance rich in carbon so that the resulting metal will contain from 0.75-1.50 per cent. carbon, it makes a steel which is largely used for cutting tools and similar purposes, and is the highest in quality and price.

Electric Iron and Steel.—Electric furnaces, introduced since 1900, are coming into use, yielding a higher grade of steel than the crucible process; they are also the only means of producing some of the "ferro-alloys," because sufficiently high temperatures cannot be otherwise obtained, and because operations can be carried out in a non-oxidizing atmosphere.

Electrolytic Iron.—Ferrous chloride solution is used as the electrolyte, cast iron as the anode and a revolving mandrel as the cathode; the iron is of 99.97 per cent. purity, with traces of carbon, silicon, sulphur and phosphorus. Before stripping the iron tube, the mandrel with deposited iron is heated to expel hydrogen, which causes brittleness in the iron to such an extent that it can be powdered. This iron is almost as soft as pure copper or aluminum, has better cold-working or drawing qualities, is resistant to corrosion or tarnishing, has 10 to 20 per cent. greater conductivity than steel and if copper-clad will have the conductivity increased by

another 20 per cent. without showing the objectionable stretching qualities of copper in transmission lines. Thin tubes, which are the most expensive to make, are made directly by this process.

By using a graphite anode, some of the ferrous chloride is oxidized to ferric chloride and this can be used to react with sulphide ores, forming ferrous chloride and precipitating sulphur; the ferrous chloride solution is electrolyzed and the cycle of reactions gives 97 per cent. of the iron and 90 per cent. of the sulphur content of the ore.

Analytical Constituents of Iron and Steel.

Until a comparatively recent period the differences between wrought iron, steel and cast iron were explained on the basis of the carbon content, the lowest amount in wrought iron and the highest amount in cast iron. In the analyses of iron and steel, combined carbon, graphitic carbon, sulphur, phosphorus, silicon and manganese were reported.

Combined carbon was known to increase the strength of steel up to about 0.9 per cent., after which it has a weakening effect; it decreases the ductility, toughness, malleability, magnetic power and electric conductivity; it increases the hardness and brittleness.

Graphite is found as a rule only in "mottled" and "gray" cast irons.

Sulphur increases the "red-shortness" of iron and steel (brittleness at a red heat); it should not exceed 0.10 per cent. and in high grades less than 0.035 per cent. is specified; present as manganous sulphide, and if Mn be insufficient also as ferrous sulphide.

Phosphorus increases the "cold-shortness" of the metal (brittleness at ordinary temperatures), especially if the metal be subjected to shock; is present as phosphide and, if in fairly large quantities, frequently segregates and appears during the turning, cutting and filing as harder and whiter masses which are known to the workmen as "ghosts."

Silicon may be present as silicide but more generally as silicate in entrained slag of which very little should be present in good steel; chemical analyses report total silicon; is added to steel to prevent gas bubbles or blowholes and is added to cast iron to precipitate carbon in the graphitic form, thus softening the metal.

Manganese is added to steel to remove sulphur and dissolved oxide and to neutralize the harmful effect of the oxygen which it is

not able to remove; manganese oxide and sulphide are not as
harmful to steel as iron oxide and sulphide. Steel free from man-
ganese is difficult to roll and requires special care for successful
shaping.

Corrosion of Iron and Steel.

This constitutes the greatest weakness of iron and steel from
the industrial standpoint and involves a loss of millions of dollars
each year. It is now recognized that the quality of manufacture
has a much greater effect than the process of manufacture. The
rusting of iron requires both oxygen (air) and water; neither one
alone can cause rusting. Iron or steel with entangled slag, occluded
gas, blowholes or which is not of uniform composition (segrega-
tion) will rust more rapidly, due to the development of a difference
of potential. After rust spots once show, corrosion is intensified
because the rust (ferric hydroxide) acts negatively towards the
metal, thus producing a difference of potential.

A number of the more familiar metals (many of which are
used for the protection of iron) arranged in the order of their
diminishing solution tensions gives the following tension series:
Mg, Zn, Al, Cd, Fe, Ni, Ph, Cu, Sn, Sb. Metals having higher
solution tensions (those preceding iron in this list) will protect
iron from corrosion until they have entered solution or have been
oxidized; metals having lower solution tensions (those following
iron in this list) will protect iron if they form a continuous coating,
but should the coating be broken the corrosion of the iron will be
more rapid.

Iron which has been dipped in certain strong oxidizing agents
no longer exhibits a solution pressure when dipped in dilute electro-
lytes and comports itself as though it were a noble metal; dipped
in fuming nitric acid it no longer dissolves in dilute acid nor does
it displace copper and silver from solutions; as this so-called "pas-
sive" condition is not a stable condition there is a continual tendency
at work which causes the return to the normal surface condition.
Chromic acid and chromate solutions also produce this unstable
state; iron immersed in a potassium dichromate solution (1 : 13000),
with access of air, showed no signs of rusting after two months.

These statements can be illustrated by making so-called "Fer-
roxyl" mounts: A 1.5 per cent. aqueous solution of agar-agar is
made by boiling for one hour, replacing the evaporated water, fil-
tering while hot, adding 2 cc. phenolphthalein solution for every

100 cc., neutralizing exactly with KOH or HCl as may be necessary, and finally adding 7 cc. of potassium ferricyanide solution (1 per cent.) for every 100 cc. Enough of this solution is poured into a Petri dish to cover the bottom and congealed by floating the dish in cold water; the specimens are then placed on this bed of jelly, completely covered with more of the hot reagent, and allowed to cool without disturbance. The colors, red at the negative and blue at the positive pole, sometimes show up immediately, but may require from twelve to twenty-four hours to attain their most perfect development. Imbedded metals, sheet iron or nails: The red color develops where the iron is protected, the blue color where it is oxidized; frequently several poles are noticed due to non-uniformity (segregation) of the metal. Iron and zinc in contact with each other: The iron will be protected (red color) while the zinc will be oxidized (shown by a white coating). Iron and copper in contact with each other: Will show the copper protected (red color) while the iron is oxidized (blue color). Two specimens of the same iron, one of which is rendered "passive" by immersion for several hours in a potassium dichromate solution, not in contact with each other, will show that the "passive" does not respond. The mounts may be preserved for months by keeping the agar covered with alcohol.

A modification of this test is used to reveal pin holes in tin plate due to imperfect coating: Acidify a hot 15 per cent. gelatin solution with dilute sulphuric acid, add a small quantity of potassium ferricyanide solution and float upon the surface of the tin plate to be tested; the gelatin solution solidifies upon cooling and in a very short time every pin hole on the tin surface will be marked by a spot of Turnbull's blue.

Preservation of Iron and Steel.

There are a number of specimens of manufactured iron which have withstood the action of the elements for long periods; the most notable is the iron column of Kutab Minar in Delhi, India, said to have been erected in 900 B. C., but also stated to be sixteen hundred years old. Chains and structural iron in use for fifty to one hundred years, and still in good condition, on analysis disclosed the presence of 0.35-0.54 per cent. copper. At the present time a large quantity of copper-steel containing 0.2-0.3 per cent. copper is being used for galvanized and tinned iron; exposure of this

copper-steel, without any protecting coating, for over five years failed to show any notable signs of corrosion.

Steel used for rails, chains, implements, boiler tubes, *etc.*, cannot be protected by any coating; for this class the problem of preservation will likely depend upon the manufacture of a purer iron, homogeneous in character, or possibly upon the discovery of a cheap rust-resisting alloy; the alloys first known to have this property contain Ni, Cr, Va, and are too expensive. Iron is now made in quantity containing 0.16 per cent. total impurities, also a copper-steel containing 0.2-0.5 per cent. copper, both announced as quite resistant to corrosion.

Boilers and Boiler Tubes.—The corrosion of these is due to electrical action and to oxygen. Zinc, as a more electro-positive metal, has been used to prevent corrosion, but is not entirely satisfactory because good contact cannot be maintained between it and the iron, and also because the area in which the protective action takes place is restricted; a number of organic reducing agents, tannin, pyrogallol, *etc.*, have been used to remove oxygen. Alkaline hydroxides, carbonates and phosphates have preservative action in addition to the property of softening the water and preventing the formation of scale. Soluble chromates, for reasons before stated, are in use as protecting agents. The most practical method depends upon the exclusion of oxygen from the feed water; by using feed-water heaters all dissolved gases can be expelled before the water enters the boilers.

Metallic Coatings.

Galvanized Iron.—Probably over one-half of the zinc produced is used for the protection of iron, which is due to its higher solution tension and is accomplished mainly at the expense of its own destruction.

Three methods are used in galvanizing iron:

(1) The "hot dip" or hot-galvanized method in which iron is cleansed by passing through HCl (sometimes $ZnCl_2$ and NH_4Cl are added) before entering the bath of molten zinc. If pure zinc were used at the start it would be speedily contaminated with iron; commercial zinc or spelter contains Pb, Cd and Fe. If the deposited zinc contains above 3 per cent. iron, the coating becomes too brittle

to bend; lead up to 1 per cent. is harmless, but 1.5 per cent. will not dissolve in the zinc, but will segregate and if deposited on the iron will form weak spots; the scum forming on the surface of the molten zinc also prevents an even and homogeneous layer of zinc. The crystalline surface on galvanized iron is improved by the addition of a small quantity of antimony to the zinc.

Pure zinc dissolves slowly in acids, but impure zinc by local currents dissolves rapidly; iron, coated with impure zinc, is more rapidly corroded.

(2) The wet-galvanized, cold, or electrolytic method, as the name indicates, deposits the zinc from solution. The deposit is practically pure zinc, but more porous than in the "hot-dip" method; the process is slow and after the coating attains a certain thickness the deposit has a tendency to become rough and crystalline; there is also difficulty in securing an even distribution of current, especially on irregularly shaped articles.

(3) The vapor-deposition or Sherardizing method is effected in two ways, namely, the "zinc-dust process" and the "molten zinc vapor process." In the former, zinc dust and the iron articles are heated to about 600° F. (315° C.) in an air-tight iron drum placed in a gas-fired furnace. In the latter the materials to be coated are placed in a cage or hollow drum which is slowly rotated inside of a cylinder into which zinc vapor and hydrogen gas or other reducing agent are forced. An advantage of the vapor-deposition method is the even coating on screw threads, pipe fittings and machine work. Sherardized material on exposure assumes a peculiar black, sooty color and then appears to be very resistant to corrosion.

Cross-sections of articles coated by the three methods and etched with iodine show in the electrolytic method only zinc and iron (no alloy); in the other two methods there are shown zinc, zinc-iron alloy and iron.

Tinned Iron or Tin Plate.—Tin is next to zinc in importance for protecting iron; the method employed for coating iron is similar to the "hot-dip" method for galvanizing. Tin, electro-negative to iron, has such a low solution tension that it is practically incorrodible. The most important uses are for roofing, cans and tinned utensils. Coatings on steel are apt to contain pin holes, but prevented by the addition of ferro-phosphorus to the steel.

Terne Plate.—Made by immersing sheet iron in a bath of molten lead-tin alloy; may contain as high as 88 per cent. lead, used extensively for roofing.

Lead-Coated Iron.—This is of minor importance; 7 per cent. or more of tin present with the lead.

Copper-Coated Iron.—Made by immersion in copper sulphate solution or by electrolytic deposition; used in form of wire, sheet and plate metal, also for cheap hardware, in which case it is generally given a sulphide treatment and burnished, producing a mottled effect.

Brass-Coated Iron.—Made by electrolytic deposition; used for imitations of genuine brass articles as hardware, jardinieres, curtain rods, *etc.;* unless protected by lacquer will rust.

Nickel-Coated Iron.—Made by electrolytic deposition; used for hardware, bathroom fixtures, *etc.;* gives better service than the two preceding, especially if lacquered.

Chromium-Coated Iron.—The electrolytic deposition of chromium upon iron, steel and other metals is a recent achievement; resistant to corrosion and dilute acids.

Antimony-Coated Iron.—Deposited from antimony chloride solution; used on rifle and gun barrels as a protection against rusting.

Aluminum-Coated Iron.—Process known as "Calorizing"; operation similar to Sherardizing, using, instead of powdered zinc, a mixture of powdered aluminum and aluminum oxide; used to protect iron at high temperatures; the diffusion of aluminum into iron proceeds slowly up to $900°$ C., rapidly between $1000°$ and $1200°$ C.; at high temperatures forms a closely adhering coating of aluminum oxide which prevents the corrosion of the iron. Used for wire, heating units, grids, stove burners, gas engine exhaust mufflers, condensers for cracking oils, glass-annealing ovens, *etc.*

These various treatments have for their object the preservation of iron; *Feralun* is a product which protects man from accidents due to worn or smooth iron and is made by pressing some hard abrasive into molten iron. Used for stair treads and all other flat surfaces upon which persons are likely to slip.

Metallic Oxide Coating.

Magnetic Oxide of Iron (Fe_3O_4).—This is produced by heating iron or steel in a coating chamber to 800-1000° C. and injecting superheated steam; the operation is repeated until a sufficient coating is obtained.

The same result may be produced by making the iron the anode or positive pole in a hot NaOH electrolyte, using a high amperage and low voltage current; to obtain a coating of sufficient thickness the poles may have to be reversed several times.

The deposit is negative to iron; therefore protection is afforded the iron only so long as the coating is perfect; damage to the coating with exposure of the iron will lead to accelerated corrosion.

Useful for hardware, grillings, railings, scroll and fancy work; Russia Iron, used for stovepipes, locomotive cases, *etc.*, has a coating of the same composition.

Paint and Lacquer Coatings.

The great bulk of finished iron and steel is protected by coating with paint. In the study of paints the pigments and vehicles must be considered. Slightly soluble chromates are used as pigments, due to the action of soluble chromates in preventing the rusting of iron.

Pigments are classified as inhibitive (rust-preventative), neutral or indeterminate and stimulative (rust-accelerating); as soluble salts, electrolytes, stimulate corrosion pigments should be thoroughly washed to insure removal of foreign salts.

Vehicles.—Linseed oil, first in importance, owes its value to the property of drying when exposed to the air; the drying can be hastened by boiling the oil with oxides and salts of metals, as zinc, lead, manganese, which act as carriers of oxygen. The film of dried oil, called linoxyn, should be elastic and hard but not brittle; it always contains voids or pores and is not waterproof, even if mixed with pigments in the finest powders. The addition of solutions of varnish gums will fill up these pores and render the film more resistant to gases and moisture. Linseed oil, applied to iron and allowed to dry, becomes an active stimulator of corrosion if the film is abraded in the least degree; this action is reduced in a marked degree if pigments are first mixed with the oil. Boiled linseed oil, as stated above, contains small quantities of metallic compounds

which aid its drying; as a paint vehicle raw or unboiled linseed oil is mixed with boiled oil (2:1) or the latter replaced by a small amount of so-called

Japan driers, which are made by fusing resins with the metallic compounds mentioned under linseed oil, and dissolving the product in turpentine.

Chinese wood oil, after boiling with metallic compounds which act as carriers of oxygen, will form on exposure a hard, elastic film, more moisture-resistant than that from linseed oil; used with linseed oil gives a glossier film.

Soja bean oil, unboiled, dries slowly; mixed with an equal volume of heavy blown linseed oil gives good results; boiled, has been used for varnishes.

Turpentine, used as a diluent or thinner, makes paint flow more easily, but if used in too large quantities gives a matt, porous surface.

Liquid Coatings.

Paints.—Liquid mixture containing pigments, linseed oil, drier, varnish, and turpentine; small additions of paraffin and carnauba wax make paint more waterproof. Rust-stimulating pigments should never be placed in contact with iron or steel surfaces; an inhibiting priming coat should always intervene; this inhibiting coating may be suitably compounded of inhibitors or of any of the indeterminate or neutral pigments reinforced with a small proportion of the stronger inhibitors; over this priming coat the air- and moisture-excluding coats can then be safely applied.

The Paint Manufacturers' Association of the United States furnished the American Society for Testing Materials, for the purpose of observation, a series of several hundred iron plates 24x36 inches, very carefully painted with paints made up of various pigments. These panels were set up near Atlantic City, N. J., in the fall of 1908, and annual inspections made to determine the relative protecting value of the different paints. These were graded on a basis of 1-10 and grades of excellence were marked 8-10; the following table shows the ratings (in the last three years only the ten highest are given):

	1910	1911	1912	1913	1914
American Vermilion	9.8	10.	9.9	9.8	7.5
(Basic lead chromate)					
Chrome Green (blue tone)	9.7	9.8	8.6	7.6	5.
Zinc and Barium Chromate	9.7	9.5	8.5	7.8	—
Sublimed Blue Lead	9.6	8.3	9.	7.2	6.
Lead and Zinc Chromate	9.5	9.7	9.2	8.3	4.
Magnetic Oxide of Iron	9.5	9.5	8.6	7.8	4.
Sublimed White Lead	9.5	9.	8.1	—	—
Zinc Chromate	9.4	9.5	8.8	8.	4.
Prussian Blue W. S.	9.2	9.	—	6.7	—
Bright Red Oxide of Iron	9.3	8.1	—	—	—
Natural Graphite	9.1	6.8	—	—	4.
Medium Chrome Yellow	9.	7.7	—	—	—
Orange Mineral	9.	8.3	—	—	—
White Lead (Quick Process)	8.9	4.2	—	—	—
Willow Charcoal	8.8	8.8	8.6	7.9	4.5
Prussian Blue W. I.	8.8	8.5	—	—	—
Red Lead	8.7	8.3	8.1	—	4.
White Lead (Dutch Process)	8.7	3.7	—	—	—
Zinc Lead White	8.	4.7	—	—	—
Venetian Red	—	8.	—	—	—
Carbon Black + Barytes	—	—	—	6.8	5.

Lacquers.—Gum lacquers are made by dissolving gums like kauri, sandarac, shellac, in alcohol, acetone, fusel oil, *etc.* Applied with a brush and sometimes baked.

Cotton lacquers are solutions of soluble guncotton or cellulose acetate, or phosphate, in amyl acetate and diluted with acetone, wood alcohol, benzin, *etc.* Articles to be coated must be dipped, as brushing causes streaking.

Combination lacquers are mixtures of the two preceding classes, the solvents of which have been properly adjusted to prevent settling out or curdling of either constituent.

Lacquers have not been used to any extent for protecting iron or steel, but a chromated lacquer has given good results in protecting iron articles on a small scale; it is made by dissolving shellac in alcohol, filtering and adding chromic acid in very small portions until the solution is saturated. To prevent the alcohol from catching on fire, the solution should be kept cool.

Coal Tar.—Refined by heating to remove water, acetic acid and some of the lighter oils, has been found useful applied alone or after admixture with lime and portland cement.

Baked Japan.—Compounded largely of high-grade asphaltic gums with kauri or other fossil gums, are applied by dipping; the material to be protected is heated and, after coating, baked until hard.

Enamel.—Used as a protection for sheet iron and culinary utensils. A fusion is made from 30 parts powdered feldspar and 25 parts borax, the melt powdered and mixed with 10 parts kaolin, 6 parts feldspar, 1.75 parts magnesium carbonate and sufficient water to make a paste, which is spread over the cleaned iron; upon this is applied a fusible powder made by fusing 37.5 parts quartz, 27.5 parts borax, 50 parts stannic oxide, 15 parts sodium carbonate and 10 parts potassium nitrate; the coated article is then dried in a hot room and heated in a muffle furnace to about 700° C. to fuse the enamel.

Robertson Process Asbestos-Protected Metal.—Used for roofing, sidings, water conductors, *etc.;* fastened with Sherardized bolts. Cleaned sheet steel is asphalt-coated, then encased in asbestos felt saturated with asphalt and, finally, covered with a waterproof coating applied at a high temperature. Not acted upon by acid vapors.

Applications.

Iron and steel articles are frequently coated with mineral oil or grease; if these articles are to be painted, this oil or grease must be removed; otherwise the paint will not dry perfectly.

Structural metal is most generally primed with red lead, but as this pigment is made by several processes the products may not furnish the same protection. A high-grade hematite with 2 to 5 per cent. zinc chromate is as effective as good red lead.

Railroad ties, poles and posts, which are partly sunk into the ground, are best protected by a hot application of a mixture of coal tar, lime and portland cement.

Pipes coated with linseed oil are afterwards immersed in heated coal-tar pitch, or a mixture of this with linseed oil, and baked.

Galvanized iron, because of the greasy nature of the zinc coating, is difficult to prime; if sharp-toothed siliceous pigment ground in varnish is well applied, subsequent coatings may be of any desired formula; sometimes the surface is wetted with a copper solution, the separated copper, after drying, offering less difficulty in priming.

Tinned iron in its manufacture is generally coated with a film

of palm oil, which should be removed by use of turpentine or benzin; A good priming coat is made of 98 per cent. ground hematite and 2 per cent. zinc chromate ground in oil with or without the addition of varnish.

Refrigeration machinery protection has been one of the most difficult problems; a priming coat containing asbestine (magnesium silicate), willow charcoal, red lead and zinc chromate ground in oil with the addition of 40 per cent. kauri-gum varnish has given excellent results.

Letter boxes, which looked so nice with their coating of aluminum paint were not protected from corrosion; a good bronze-green, inhibitive, can be made from zinc oxide and chromate, white lead and willow charcoal.

Ships' bottoms: Formulas found satisfactory by the Government are as follows: Anti-corrosive paint—7.25 gals. grain alcohol, 7.9 lb. shellac, 0.6 gal. turpentine, 0.6 gal. pine-tar oil, 9.5 lb. dry metallic zinc and 28.5 lb. dry zinc oxide. Anti-fouling paint—6 gals. grain alcohol, 13.75 lb. shellac, 1 gal. turpentine, 1 gal. pine-tar oil, 13.75 lb. dry zinc oxide, 13.75 lb. Indian red and 4.75 lb. red mercuric oxide. Both formulas make ten gallons.

Behavior of Iron and Iron-Carbon Alloys During Cooling.

The important stages in developing the modern view of the constituents of iron and steel are as follows:

Widmanstetten in 1808, microscopic examination;

Anossow in 1856, microscopic examination of metallurgical specimens;

Sorby in 1864, microscopic examination after etching;

Osmond and Werth in 1883, study of the changes due to quenching;

Osmond in 1894, classical study of the constitution of iron and steel;

An international committee report in 1912 on the nomenclature of iron and steel constituents.

Pure iron is capable of existing in three allotropic modifications; if a cooling curve be taken of the purest iron, obtained by electro-deposition, two remarkable irregularities (transformations) occur in the curve, due to evolution of heat in each case, and attended by important changes in the physical properties. The first

of these transformations is noted at (G) 917° C. and is due to the change of gamma-iron into beta-iron; the second transformation is noted at (M) 769° C. and is due to the change of beta-iron into alpha-iron.

Alpha-iron exists below 769° C., beta-iron between 769° and 917° C., gamma-iron above 917° C.; the first two crystallize in cubes and are capable of forming isomorphous mixtures; gamma-iron crystallizes in octahedra and does not form isomorphous mixtures with beta-iron but is the only one of the three which can dissolve carbon, forming a solid solution, known as austenite; alpha-iron only is magnetic. The temperatures stated, varying from those indicated in the illustration, are taken from L. Guillet and A. Portevins's "Metallography and Macrography," 1922.
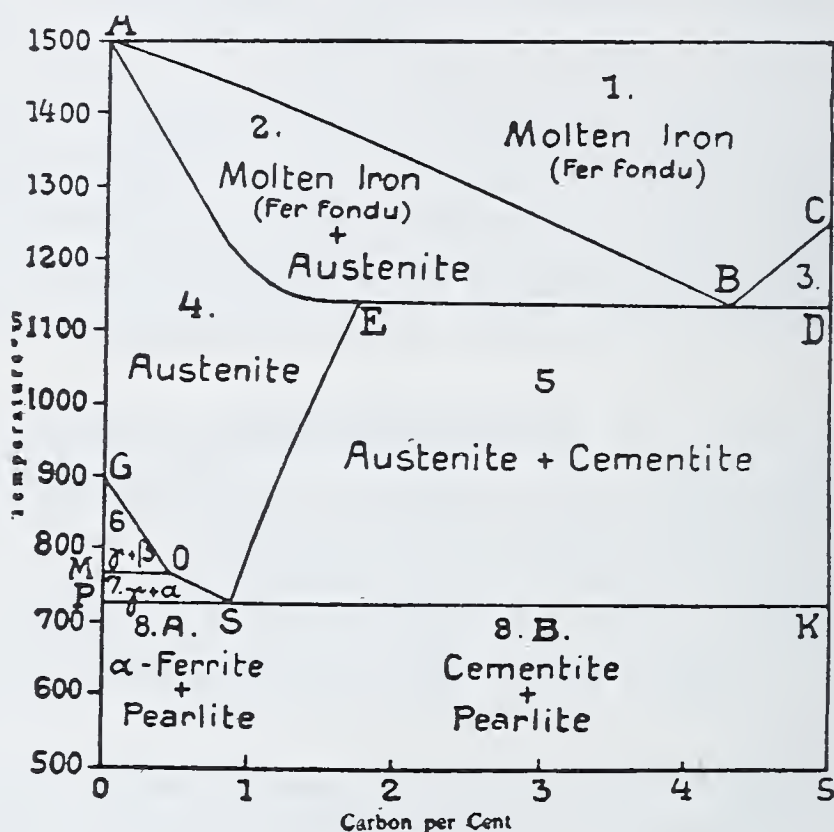
Steels containing up to 0.3 per cent. carbon give three transformation points, shown by the lines G-O, M-O and P-S; G-O indicates the separation of beta-iron, the carbon concentrating in the remaining austenite; M-O the conversion of beta-iron into alpha-iron; P-S the separation of alpha-iron with the breaking down of the austenite into pearlite (0.9 per cent. carbon) and alpha-iron. The final constituents therefore are ferrite (alpha-iron) and pearlite (an aggregate of six parts of ferrite and one part cementite).

Any point along G-O is frequently indicated as "A_3"; the temperature of which decreases with increasing carbon content and

eventually may merge with "A_2" on the line M-O, the temperature of which is independent of the carbon content; points along the line P-S, frequently indicated as "A_1", correspond to the formation of pearlite (also called "the eutectoid") the quantity of which increases with the carbon content up to the point S, 0.9 per cent. carbon.

These transformation points may be reached by cooling from a higher temperature or by heating from a lower temperature; to make a distinction the former are indicated as "Ar_3", "Ar_2", and "Ar_1"; the latter as "Ac_3", "Ac_2", and "Ac_1"; "Ar_1" is also known as the "recalescence" point because attended by a considerable evolution of heat; "Ac_1" therefore must be attended by a corresponding absorption of heat.

Steels containing between 0.3 and 0.9 per cent. carbon give two transformation points: the $A_{3.2}$ point, corresponding to the line O-S, is depressed as the carbon content increases and indicates the separation of ferrite from some of the austenite with concentration of carbon in the remaining austenite; the A_1. 725° C. with the change of the remaining austenite into ferrite and pearlite.

Steels containing between 0.9 and 1.7 per cent. carbon have two transformation points: the first along the line S-E (E 1130° C.) corresponds to the separation of cementite, Fe_3C (6.7 per cent. carbon); this point rises rapidly with the carbon content and is frequently indicated as Acm; when the austenite reaches a carbon content of 0.9 per cent. the second point $A_{3.2.1}$ indicates the change into pearlite.

Steels containing over 1.7 per cent. carbon have but one transformation point, namely, $A_{3.2.1}$ along the line P-S.

Alloys containing between 1.7 and 4.3 per cent. carbon will deposit during solidification austenite along A-B and solidification will be completed by the formation of the eutectic, cementite-austenite, at B; from this solid solution cementite separates until 1.7 per cent. carbon is left in solution at point E 1130° C. and 0.9 per cent. carbon at point S 725° C., at which temperature pearlite is formed.

Alloys containing between 4.3 per cent. and 6.7 per cent. carbon will deposit during solidification cementite along B-C and solidification will be completed by the formation of the eutectic, cementite-austenite, at B; further changes then as in the preceding case.

Constituents of Steel and Cast Iron.

Ferrite and cementite are distinguished according to their source:

Pro-eutectoid ferrite separating along the line G-O-S found in 7 and 8A.

Pearlitic ferrite, constituent of pearlite, found in 8A and 8B.

Pearlitic cementite, constituent of pearlite, found in 8A and 8B.

Pro-eutectoid cementite separating along the line S-E, found in 5.

Eutectic cementite separating along the line B-D, found in 5.

Primary cementite separating along the line B-C, found in 3.

Graphite, found as a rule only in "mottled" and "gray" cast iron.

Ferrite.—Free alpha-iron, nearly pure; may contain a little phosphorus and silicon, and at the most 0.05 per cent. and perhaps never as much as 0.02 per cent. carbon. In addition to the sources already given, it may be formed by the decomposition of pearlite in low-carbon steels, of cementite under abnormal conditions, and may be found uncoagulated in sorbite and probably in troostite. Hardness 3.5-3.7, therefore soft, relatively weak, very ductile, strongly magnetic; has tensile strength, 40,000 pounds per square inch.

Pearlite.—The iron-carbon eutectoid consisting of alternate masses of ferrite and cementite, is a conglomerate of about 6 parts ferrite and 1 part cementite, containing 0.9 per cent. carbon and 99.1 per cent. iron; one of the final products in the transformation of austenite. Under high magnification, both ferrite and cementite are revealed.

Cementite.—Ferric carbide Fe_3C. (Manganese and other metals may replace the iron forming tricarbides, called "manganiferous cementite," *etc.*). In addition to the previously given sources of cementite it also occurs uncoagulated in sorbite, troostite and possibly martensite; as spheroidized cementite in steels quenched from high temperatures. During annealing may break up into graphite and austenite above A_1 or into graphite and ferrite below A_1; the graphitizing tendency is completely checked in the cold, but increases with the temperature and with the proportion of carbon and

silicon present and is opposed by the presence of manganese and chromium.

It is the hardest component of steel, having a hardness of 6, scratches glass and feldspar, but not quartz, and is very brittle.

Graphite.—Probably pure carbon, identical with natural graphite; derived wholly or in large part from cementite; forming small, black, rounded particles surrounded by ferrite, in annealing may separate from cementite and austenite. Very soft, hardness 1-2; flexible; soils paper; greasy to the touch. After polishing, graphite appears as black areas, under the microscope.

The important constituents looked for in the microscopic examination of prepared surfaces (metallography) include in addition to those mentioned some transition products and also some inclusions due to impurities.

Austenite (sometimes wrongly called martensite) is a solid solution of carbon (or iron carbide) and gramma-iron and may have any carbon content up to saturation, 0.9 per cent. at S (725°C.) to 1-7 per cent. at E (1130° C.). Very ductile and slightly magnetic.

It is normal and in equilibrium in 4, associated with gramma-iron in 6, with alpha-iron in 7, and with cementite in 5. In cooling slowly through $A_{3.2.1}$ austenite shifts its carbon content spontaneously through generating ferrite or cementite to the eutectoid ratio, 0.9 per cent., and then transforms with increase of volume into pearlite, with which the ejected ferrite or cementite remains mixed.

Rapid cooling and the presence of carbon, manganese and nickel obstruct this transformation; hence, by combining these four obstructing agents in proper proportions, the transformation may be arrested at any of the intermediate stages (martensite, troostite or sorbite) and, if arrested in an earlier stage, it can be brought to any later desired stage by a regulated reheating or "tempering."

A rapid cooling in the absence of these obstructing elements checks the transformation but little and only temporarily, yet if aided by the presence of a little carbon the transformation is wholly arrested in the martensite stage, in the presence of 1.4 per cent. carbon rapid cooling retains about one-half the austenite so little altered that it is considerably softer than the usually dark needles of the surrounding martensite, with which it sharply contrasts.

About 1 per cent. carbon with 12 per cent. manganese, or about

25 per cent. nickel lowers and obstructs the transformation to such a degree that austenite persists, apparently unaltered, even through a slow cooling.

Austenite is never associated with ferrite and pearlite.

Martensite.—The early stage in the transformation of austenite, characterized by needle-like structure and a hardness which is greater than that of any other constituent of the same carbon content; the hardness and brittleness increase with the carbon content up to 0.9 per cent. It is magnetic and is the chief constituent of hardened carbon tool steels and of medium nickel and manganese steels. It represents a meta-stable condition in which the metal is caught during rapid cooling in transit between the austenite condition, stable above A_1, and the condition of ferrite plus cementite into which the steel habitually passes on cooling slowly past A_1.

In 1.5 per cent. carbon steel, rapidly quenched, it is associated with austenite; in more fully transformed steels (low-carbon steels, hardened; high-carbon steels, oil hardened, or water hardened and slightly tempered; or hardened thick pieces even of high-carbon steel) it is associated with troostite and with some pro-eutectoid ferrite (in hypo-eutectoid steels) or pro-eutectoid cementite (in hyper-eutectoid steels).

In tempering it first changes successively into troostite, osmondite, sorbite and at about 700° C. into granular pearlite, which, on heating into the transformation range, changes into austenite, and this on cooling yields lamellar pearlite. Characteristic specimens are obtained by heating bars, 1 cm. square, of eutectoid steel (0.9 per cent. carbon to 800° C. and quenching in cold water.

Troostite.—An uncoagulated conglomerate of the transition stages following martensite, with which it is habitually associated; carbon content varies considerably. May arise either on reheating hardened (martensitic) steel to slightly below 400° C., or by cooling under proper conditions through the transition range; higher reheating will form sorbite, then pearlite.

Osmondite.—That stage in the transformation of austenite at which the solubility in dilute sulphuric acid reaches its maximum rapidity; arbitrarily taken as the boundary between troostite and sorbite. Hardened 1 per cent. carbon steel reheated to 350-400° C.

passes through the stage of troostite to that of osmondite and on higher heating to that of sorbite. Conditions to bring hardened steels of other carbon content to the osmondite stage are not known.

Sorbite.—An ill-defined, almost amorphous, conglomerate of irresoluble pearlite with ferrite (in hypo-eutectoid steels) or cementite (in hyper-eutectoid steels), lighter in color and softer than troostite for the same carbon content; usually associated with pearlite, but differing from this in that the individual constituents are not revealed under high magnification (irresoluble). Formed (1) by reheating hardened steel to a little over 400° C., but not to 700° C., at which latter temperature it coagulates into granular pearlite; (2) by quenching small pieces of steel in oil or molten lead, or even by air-cooling them; (3) by quenching in water from just above the bottom of the transition range A_1. Sorbite remains unchanged below 400° C.

It is slightly less ductile than pearlitic steel for given carbon content, but its tenacity and elastic limit are so high that a higher combination of these three properties can be had in a sorbitic steel than is possible in a pearlitic steel of somewhat higher carbon content; hence the use of sorbitic steel for structural purposes needing the best quality.

Inclusions.—These represent impurities present in iron-carbon alloys which are insoluble in these alloys at ordinary temperatures, and may be seen by microscopical examination before etching; they consist of the oxide, sulphides and silicates of iron and manganese and phosphides of iron, and represent either entrained slag or segregations which in good metal should be present in but small quantity and evenly distributed. A few other inclusions are due to additions made to produce better iron and steel.

Aluminum, because of its powerful deoxidizing property, is added to steel to prevent the retention of gas bubbles or blowholes; the gas may be entangled air or carbon monoxide produced from the carbon of the metal and atmospheric oxygen. Aluminum oxide is difficulty fusible and therefore hard to remove.

Titanium, added to iron and steel, has the property of removing the last traces of dissolved oxygen and nitrogen, as well as increasing the fluidity of entangled oxides and slag in steel castings and

ingots, which enables their more ready separation from the metal. Titanium nitride may be found under the microscope.

Zirconium rapidly removes oxygen and nitrogen, and the last traces of ferrous sulphide difficulty removable by manganese; zirconium nitride appears as small, yellow cubical crystals under a magnification of 500 diameters.

Microscopical Examination.

Emery, corundum and alundun (composition Al_2O_3); crystalon and carborundum (composition SiC) are the abrasives used for grinding small sections, about one-half inch square, of the specimens to be examined; coarser grades are used at first, followed by finer grades until the final surface is perfectly polished and free from scratches.

The examination is made, as for all opaque objects, by reflected light, and should be conducted in three stages: After receiving as perfect a polish as possible, it should be examined to determine the quantity, distribution and nature of the slag; then it should be lightly etched to reveal the quantity and condition of the carbide occurring as pearlite, cementite, sorbite, *etc.;* finally, it should be deeply etched to show the crystalline structure.

Usually a magnification of 200 diameters is common, but sometimes as low as 50 and occasionally as high as 500 and even 1000 diameters are used.

Inclusions, slag, may be of various colors, as gray, black, fawn, brown and sometimes blue; under high magnification, masses may reveal individual constituents:

Manganese sulphide: Pale dove or slate-gray masses; rounded in castings; ductile therefore in rolled metal or forgings appears elongated; with acid etchants liberates H_2S and the surface becomes pitted (distinction from silicate).

Ferrous sulphide: Yellow or pale brown in color; brittle; with acid etchants responds like MnS.

Iron phosphide: Whiter than the surrounding metal; blackens with sodium picrate.

Manganese silicate: Darker than the sulphide.

Ferrous silicate: Dark.

Aluminum oxide: Most difficulty fusible inclusion.

Titanium nitride: Pink crystals.

Tests for sulphides and phosphides: (1) The polished surface is covered with silk impregnated with an acidified mercuric chloride solution; local darkening indicates the sulphide areas; phosphides produce lemon-yellow mercuric phosphide. (2) The polished surface is covered with silver bromide paper moistened with 3 per cent. sulphuric acid; the sulphide and phosphide areas are shown by the formation of black sulphide and phosphide of silver. Phosphides do not respond as quickly as sulphides in these tests.

Before stating the composition and action of the etchants, the structure of the iron and steel constituents under the microscope should be given:

Ferrite: Parallel plates: polygons; network; irregular figures; component cubes.

Pearlite: Conglomerate of ferrite and cementite; granular; lamellated.

Cementite: Plates; network; spheroids.

Graphite: Flaky plates; small black particles.

Austenite, generally with martensite: White irregular crystals.

Martensite: Zig-zag shapes; needle structure; plates composed of needles.

Troostite: Irregular; finely granular; almost amorphous.

Osmondite: Ill-defined.

Sorbite: Ill-defined; almost amorphous.

The last three constituents are not resolved even under the highest magnification.

Etchants.

Licorice Extract.—This was one of the first reagents giving beautiful results, but soon replaced by more rapid etchants. The specimen to be etched was rubbed vigorously upon a smooth piece of parchment, moistened with an aqueous extract of licorice, and upon which some precipitated calcium sulphate had been placed to act as a polishing powder; rubbing was continued until the structure appeared.

Ammonium Nitrate (2 per cent. solution).—This reagent, replacing the aqueous licorice extract, was found to give the same results.

Ferrite distinguished by the **crystalline structure**;

Pearlite by the unequal etching of its constituents;

Cementite and austenite are unaffected;

Martensite by the needle structure;

Troostite by the yellow, brown or blue bands merging into each other;

Sorbite by the yellow to dark-brown color.

Manipulation With Other Etchants.—With the exception of sodium picrate, the polished specimens, freed from grease by alcohol or by rubbing with the finest emery paper, are either placed in a shallow dish, covered with the reagent and rocked to keep the reagent of even strength and to dislodge gas bubbles; or else the reagent is applied by means of a brush. The operation is continued until the surface is sufficiently acted upon and then the reagent is displaced by washing with alcohol or water; in the latter case the water is removed, and drying facilitated, by using several portions of alcohol and, finally, ether.

In the case of sodium picrate, the specimens are placed in a casserole, covered with the reagent, boiled for ten minutes, then washed and dried.

Many of the etchants, in addition to developing the characteristic structures, color some of the steel constituents, which makes their recognition easier and in fact gives the means for identifying troostite, osmondite and sorbite.

Hydrochloric acid, 1 cc. (sp. gr. 1.19) to 100 cc. alcohol; unstable.

Nitric acid, 4 cc. (sp. gr. 1.42) to 100 cc. alcohol; unstable.

Picric acid, 4-5 gm. in 100 cc. alcohol.

Benedick's reagent, 4 gm. meta-nitrobenzoic acid in 100 cc. alcohol.

Iodine solution, 10 gm. iodine and 20 gm. potassium iodide in 100 cc. water.

The above reagents have practically the same action; the inorganic acids and iodine are of course the most active; ferrite and cementite do not develop color; pearlite apparently darkens, due to an effect of shadow and relief; austenite and martensite develop slowly, while troostite, osmondite and sorbite develop color rapidly. Austenite is sometimes developed by using a saturated solution of picric acid in alcohol. Graphite and manganous sulphide are revealed as dark spots in white ferrite by picric acid.

Kourbatoff's reagent: (a) 5 cc. nitric acid (sp. gr. 1.20) added to 95 cc. glacial acetic acid; (b) a mixture of equal volumes of methyl, ethyl and amyl alcohols. For use mix one volume of (a) with three volumes of (b). Used to distinguish troostite from all other steel constituents; after seven minutes immersion only troostite will be colored.

Sulphurous acid: 4 per cent. in water or alcohol solution. Colors due to austenite, martensite and troostite can be distinguished. As cementite is not colored, this reagent has been used to show cementite in troostite.

Sodium picrate: 2 gm. picric acid and 8 gm. sodium hydroxide in 100 cc. water. Only cementite and iron phosphide are blackened, the former rapidly, the latter but slowly.

Heyn's reagent: 12 per cent. cupric-ammonium chloride in water; after immersion the deposited copper is removed with 10 per cent. nitric acid. Used to show the macrographic structure of steels and to show the component cubes in ferrite.

Ferric chloride dissolved to saturation in dilute sulphuric acid will readily etch stainless steel.

Spark pictures have recently been suggested as a means of distinguishing steels of various carbon content and also of steel-alloys. The specimens, best in form of rods or bars, are pressed firmly against the rapidly revolving emery wheel; the path of the spark from its origin to its extinction forms a line of light which, at the end, branches out in every direction, having an explosion-like appearance and resembling branches of blossoms. The number of lines making up the ray, the color, and the blossom-like appearance show considerable variation, depending upon the composition of the steel.

Metals and Ferro-Alloys.

Metals and ferro-alloys used in the manufacture of various kinds of steel; generally added to the molten steel in the crucible or in the ladle:

Aluminum or ferro-aluminum, 5-20 per cent. Al; used as a deoxidizer.

Ferro-boron, 10 per cent. B; used for boron-steel, 0.5 per cent. B and 0.22 per cent. C, having high tensile strength and great resistance to shock.

Cobalt, one of the metals imparting red-hardness to steel; used in high-speed steel.

Ferro-cerium, 30-35 per cent. Ce, readily sparks with moderate friction, used in gas lighters; disintegrates after a time.

Ferro-chrome varies in composition as made by different processes: Crucible, 19.8 per cent. Cr and 3.8 per cent. C; blast-furnace, 41.4 per cent. Cr and 7 per cent. C; electric furnace, 63.5-64.5 per cent. Cr and 1-10 per cent. C; low-carbon ferro-chrome, 70 per cent. Cr and 0.5 per cent. C. Imparts great hardness; resistant to shock and corrosion; used for making chrome-steel.

Copper, to the extent of about 0.3 per cent., gives a steel withstanding atmospheric corrosion and much more resistant to dilute acids.

Ferro-manganese, the most extensively used ferro-alloy in the steel industry, 80-85 per cent. Mn, 6.5 per cent. C, 1 per cent. Si, 0.25 per cent. P, 0.01 per cent. S; spiegel-eisen contains 15-20 per cent. Mn. Used in Bessemer and open-hearth steel manufacture as a deoxidizer and desulphurizer and for recarburization. Used for softening, strengthening and purifying hard or chilled iron; for toughening soft iron; for making manganese-steel.

Ferro-manganese-silicon: Made by melting ferro-manganese and ferro-silicon. Contains 20-35 per cent. Si, 50-75 per cent. Mn and 1-19 per cent. Fe, with low carbon content because of the high Si content. Used as a deoxidizer and for manganese-silicon-steel.

Ferro-molybdenum, 50-85 per cent. Mo, 11-49 per cent. Fe and 0.35-0.4 per cent. C; used because, even in small quantities, it increases resistance to blows and because it imparts red-hardness to steel in high-speed steels. Tungsten can be replaced in alloys by one-half the quantity of molybdenum.

Nickel or ferro-nickel, 25-85 per cent. Ni; imparts toughness and resists the development of fatigue; present in certain proportions allows expansion to be regulated. Used for nickel-steels.

Ferro-phosphorus, 16-25 per cent. P; used in steel for tin plate, enabling more satisfactory rolling and coating.

Ferro-silicon, the most extensively used of all electric-furnace alloys. With Si up to 30 per cent. the alloy is hard, with no tendency to disintegrate; between 30 and 65 per cent. the alloy crumbles and falls to powder, usually accompanied by an offensive and poisonous gas (due to As, P, Si?); above 70 per cent. the alloy is brittle but will not disintegrate. Used as a deoxidizer, to prevent

blowholes, for precipitating C, thus softening cast iron (with 7 per cent. Si only graphitic carbon can be present); used for making silicon-steel.

Ferro-titanium, 10-25 per cent. Ti, 1-8 per cent. C, and 0.35-1 per cent. Si; used as a deoxidizer or scavenger for occluded oxygen and nitrogen and produces a superior surface for galvanizing and tinning; used for titanium-steel, for cutting tools, giving these greater ductility; for increasing the crushing strength of cast iron (as much as 50 per cent.).

Ferro-tungsten, 50-80 per cent. W and 0.5-4 per cent. C; used for tungsten-steel, in self-hardening, and because it imparts red-hardness, in high-speed steels.

Ferro-uranium, 30-50 per cent. U and 1.5-4 per cent. C; used for high-speed steel with V, Cr and W or Mo.

Ferro-vanadium, 30-40 per cent. V and 0.1-0.4 per cent. C; used as a deoxidizer, also to impart great strength and hardness to steel and to make it more resistant to jar.

Ferro-zirconium, 10 per cent. Zr. Silicon-zirconium, 45 per cent. Si, 35 per cent. Zr. Zirconium combines energetically with oxygen and readily forms nitrides, sulphides and carbides; 0.05-0.1 per cent. Zr sufficient as a deoxidizer and scavenger; 0.15 per cent. Zr will also fix the nitrogen and 0.22 per cent. Zr will break up the last traces of FeS (a task not readily performed by Mn). Steel, with as much as 0.19-0.22 per cent. S, after addition of Zr can be readily rolled.

Classification of Steels.

Steels are classified according to their carbon content into:

Eutectoid, 0.9 per cent. C, with pearlite as the constituent after normal cooling; in absence of other metals this gives the strongest carbon steel.

Hypo-eutectoid, less than 0.9 per cent. C, with ferrite and pearlite as the constituents after normal cooling; this class includes wrought iron, soft steel, machine steels, structural steel, railroad rails, and even a great majority of spring steels.

Hyper-eutectoid, between 0.9 and 1.7 per cent. C, with pearlite and cementite as the constituents after normal cooling; this class includes chiefly the steels used for cutting tools.

Case-hardened steels: Low-carbon steels, 0.15-0.25 per cent. C, will not harden appreciably by quenching, but will take up carbon if heated with some material containing carbon, as charcoal,

charred leather, powdered bone, or with some carbonaceous gas like CO or CO_2 (to use the latter, the steel packed in charcoal should be heated to 800-1000° C. before passing in the gas). The penetration of the carbon should not exceed 1.5 mm. (0.06 inch); the carbon on the surface may vary between 0.85 and 1.1 per cent., depending upon the use to be made of the steel; deeper penetration and excessive carbon will produce brittleness, thus defeating the object of case-hardening. Finally the steel is quenched. Case-hardened steels are used for gears and wearing and cutting parts.

Heat-treated steels, 0.2 per cent. or more C, are described as pearlitic, sorbitic, martensitic, austenitic, *etc.,* depending upon the constituents produced. The steels are heated into the transformation range above A_3 (917° C.), maintaining the temperature for some time so that the equilibrium can be established, then quenching by immersion in water, oil or sometimes molten lead; this treatment is followed if desired by annealing in which the metal is reheated to certain specified temperatures below 725° C. and allowing to cool slowly. In some cases to produce proper results the metal is heat-treated a second and even a third time; the first treatment at the highest, the second at a somewhat lower and the third at a still lower temperature.

Quenched steels, suddenly cooled from high temperatures, are the hardest and most brittle (manganese steel an exception).

Annealed steels, slowly cooled after quenching and reheating to definite temperatures, are softest and toughest.

Tempered steels, suddenly cooled after quenching, reheating to moderate temperatures and again quenched, are intermediate in properties.

Ternary alloys or special steels contain, besides Fe and C and the small amount of Mn, another metal which imparts valuable properties to the alloy. The metals found most useful are Cr. Mn. Ni, Ti, V for structural steels, and Co, Mo, W, U for high-speed steels (Cr and V are also used in this class).

Quarternary alloys contain two or more of these metals.

Self-hardening steels, as the name implies, require no quenching, result upon normal cooling or by aid of an air blast; they contain Ni, W, Mo, Mn or a mixture of Cr and Mn.

High-speed steels, used for cutting tools, containing W or Mo or a mixture of Co and Cr, are effective even though by friction the steel becomes heated to dull-redness, therefore are said to possess the property of "red-hardness"; an important discovery which

increased the durability of high-speed steels was a method of heat treatment. Tungsten high-speed steel, 0.4-0.9 per cent. C, heated to 1200-1260° C., rapidly cooled to 843° C. in a bath of molten red-hot lead kept below this temperature, and then either rapidly or slowly cooled to atmospheric temperature; it is then reheated in a lead bath to 371-671° C. and again cooled, rapidly or slowly, to atmospheric temperature. Molybdenum or cobalt high-speed steels are heat-treated as above, but the maximum temperature is 982° C.

The remarkable properties in the last two classes of steels depend upon retarding or preventing the change of austenite into pearlite. Under austenite the action of carbon, manganese and nickel was mentioned. Chromium, like carbon, increases the time required to change from the austenitic to the pearlitic condition; tungsten and molybdenum and cobalt in presence of chromium will resist the change from the martensitic condition, the first of these, tungsten, if present to the extent of 7 per cent., will entirely prevent the formation of pearlite.

Mo, V and Si (Si up to 3 per cent.) increase the cutting efficiency; Co and U increase the toughness; V decreases the necessary regrindings; W may be replaced by half the quantity of Mo.

Analyses of High-Speed Steels.   Semi-High-Speed Steels.

W	17.65%	5.44	——	W	7.56	4.78
Cr	3.76	0.4	12.5	Cr	3.34	0.69
V	0.80	——	——	V	——	——
C	0.68	2.15	1.5	C	1.19	0.94
Mn	0.23	1.58	——	Mn	0.46	0.27
P	0.02	——	——	P	0.024	0.01
S	0.02	——	——	S	0.025	0.01
Si	0.23	1.04	——	Si	0.20	0.11
Co	2.50	——	3.5	Co	——	——
Mo	0.15	——	——	Mo	——	——

Chromium Steel.

Generally contains 0.8-2 per cent. C and 1-2 per cent. Cr, in castings 3-4 per cent. Cr; used for armor-piercing projectiles, rock-crushing machinery, safes, dies, axles, springs, razors, cutlery, also for tool steel and bullet-proof steel.

Stainless steel, used for cutlery, contains 10-13 per cent. Cr, 0.2-0.3 per cent. C, 0.18 per cent. Mn and 0.11 per cent. Si; this alloy is not stainless until heat-treated, tempered and polished, the

higher the polish the more resistant will it be to fruit and dilute mineral acids; the resistance to corrosion is tested by immersion in a very strong brine. Several products have been patented as yielding stainless steel: (1) 5-7 per cent. Cr, 0.25-0.75 per cent. Mn, 31.38 per cent. Cu, 38-46 per cent. Ni, 16-20 per cent. Fe (2) Iron containing 0.2 per cent. C, 0.2 per cent. Cu, 0.1 per cent. Mo.

Rustless iron, 13-16 per cent. Cr, 0.1 per cent. C. This is more ductile and more readily machined, forged and rolled than iron. In making this alloy the ferro-chromium used must not contain over 0.5 per cent. C and the expense of this low-carbon ferro-chromium has restricted its use. Marine growths will not adhere to plates of rustless iron.

Thermalloy, 24-26 per cent. Cr, 0.5-0.6 per cent. Mn, 0.8-1 per cent. C, 0.7-0.75 per cent. Si, not over 0.04 per cent. S and P, upon alternate heating and cooling, shows no bending, warping or cracking; does not oxidize below 1175° C. and is less affected above this temperature than any other of the so-called baser metals; the heat conductivity is over twice that of iron. Used for enamel-burning equipment, carbonizing pots, *etc.*

Duraloy, 27-28 per cent. Cr, 0.5 per cent. Mn, 0.5 per cent. Si, 0.15 per cent. S and 0.15 per cent. P.

Self-hardening steel, 4-6 per cent. Cr, 1 per cent. C and 2-3 per cent. Mn.

Other alloys contain Cr with Ni, Mo, V and W.

Manganese Steel.

Generally contains 11-14 per cent. Mn, 1-1.3 per cent. C, 0.3-0.8 per cent. Si, 0.05-0.08 per cent. P; 1-5 per cent. Mn makes the steel so brittle that it can be pulverized under the hammer; 12-13 per cent. Mn with 1.5-2 per cent. C gives an alloy which on slow cooling becomes almost as brittle as glass but, if heat-treated, becomes as ductile as soft carbon steel with a tensile strength three times as great (the result of heat-treatment differing from other alloys). Manganese steel is non-magnetic and so hard that no tool-steel will cut it, but castings and forgings may be bent and hammered like mild steel; used for jaws and wearing parts of rock-crushing machinery and steam shovels, railroad forges, rails for curves, burglar-proof safes, *etc.*

With a higher percentage of carbon, 6-9 per cent. Mn will give a steel almost equal in properties to the above.

Molybdenum Steel.

Contains 3-12 per cent. Mo, 0.6-1.5 per cent. C, and has practically the same properties as tungsten steel, but only half the quantity of Mo is necessary for same effect. Used in high-speed steel, motor-car steel, boiler plates, crank and propeller shafts, armor-piercing shells, gun barrels; the best permanent magnet steel, 3-4 per cent. Mo and 1-1.5 per cent. C; with Ni and Cr in armor plate.

Nickel Steel.

One of the most important of the structural alloy steels, contains from 3-5 per cent. Ni and 0.1-0.5 per cent. C; Ni is resistant to corrosion, prevents segregation and increases soundness in its alloys.

The alloy most generally used has about six times the life of a carbon steel, and contains 3.5 per cent. Ni, 0.5-0.8 per cent. Mn, and not over 0.04 per cent. of P and S, with carbon varying by 0.05 per cent. from 0.15-0.5 per cent.; properly heat-treated (single or double) combines great tensile strength and hardness with high elastic limit and ductility. Nickel steels are used for armor plate, automobile and bridge construction, rails, ammunition, marine shafting, in fact all kinds of machinery subjected to severe stresses. The addition of small quantities of Cr, 0.3-1 per cent., increases the tensile strength and resistance to wear.

Harveyized steel, for armor plate, contains 3-5 per cent. Ni and 1-2 per cent. Cr, case-hardened.

Self-hardening steel contains 8-25 per cent. Ni.

Resistance wire, 25 per cent. Ni and 0.7-0.9 per cent. C, used in making resistance coils.

Invar, non-expansible alloy, 36 per cent. Ni and 0.2 per cent. C, has the property of maintaining an almost constant volume through a considerable range of temperature, hence used for surveyor's tapes, measuring instruments, pendulums, etc.; does not spot with water, takes a fine polish and has a surface on which fine lines can be ruled.

Platinite, 46 per cent. Ni and 0.15 per cent. C, has replaced the platinum in electric-light bulbs because the expansion of this alloy is the same as that of platinum and glass.

Calite, a nickel, aluminum and iron alloy, resists oxidation up to 1300° C.; the protective coating of oxides adheres tightly and

does not drop off even on quenching from high temperatures; at 900° C. the loss per sq. cm. is measured in 0.1 milligrams. So hard that it cannot be machined in cast condition, nor cut with oxy-acetylene torch, but must be ground; non-corrosive; immersion in sea-salt solution at 38° C. for 200 hours does not destroy the polish; stainless steel is stated to withstand this treatment but for a few hours.

Copper alloy steel, 1.5-1.8 per cent. Ni, 0.5-0.8 per cent. Cu, and 0.3-0.35 per cent. C, is cheaper but equal to a 3 per cent. nickel steel; with the addition of 0.5 per cent. Cr the properties equal that of a 1 per cent. Cr and 3 per cent. Ni steel.

Silicon Steel.

One to five per cent. Si, in presence of the smallest possible amounts of carbon, manganese and other impurities in the iron, gives an unusually efficient magnet alloy, because of its high permeability and high electric resistance; requires a double and often a third heat treatment. Silicon steel with 2.75 per cent. Si is the most desirable alloy known for electrical generating machinery; with 0.8-2 per cent. Si and 0.7-0.4 per cent. C gives important alloys for the manufacture of springs.

Duriron, 14 per cent. Si, can be cast in any shape, very hard and very brittle, so that it cannot be machined but must be ground; resistant to oxidation and acids; used for sinks, pumps, pipes, *etc.*

Corrosiron, 13 per cent. Si, 0.3 per cent. Mn and 1.2 per cent. C.

Titanium Steel.

Steel containing 0.5-1 per cent. Ti resists abrasion, frictional wear and torsional strains; used for gears, locomotive tires, rails and castings.

Tungsten Steel.

Self-hardening steel: 4-12 per cent. W, 2-3 per cent. Mn, 1.5-2.5 per cent. C; the Mn may be replaced by 1-2 per cent. Cr and the 12 per cent. W by 4-8 per cent. Mo.

High-speed steel may contain as much as 24 per cent. W with 0.4-0.8 per cent. C; the W may be replaced by one-half the weight of Mo; a small quantity of V is added to advantage.

Magnet steel, 4-5 per cent. W and 0.5-0.7 per cent. C; if heat-treated retains magnetism better than steel.

Vanadium Steel.

Contains 0.1-0.4 per cent. V, never over 1 per cent. V. Valuable because of its resistance to shocks and stresses; used for pneumatic chisel rock drills, springs, gears, axles, hammer piston rods, aeroplanes, *etc.* Used with W, Cr, Ni, Mo.

0.9 per cent. Cr, 0.12-0.18 per cent. V, 0.15-0.5 per cent. C, 0.65 per cent. Mn and less than 0.04 per cent. S and P gives an alloy superior to nickel steel; with 0.15-0.25 per cent. C can be case-hardened.

Physical Properties of Alloy Steels.

The influence of the more important metals used in alloy steels upon the physical properties can be shown in different ways: (1) Alloys prepared to have the same tensile strength and noting the other properties; (2) alloys containing the metals in different quantities, or replacing one metal by another, and noting all of the properties. The character of the heat treatment will considerably change results of physical tests.

(A) Tensile strength, in tons per square inch; (B) elongation in two inches (ductility) in per cent.; (C) reduction in area (toughness) in per cent.; (D) resistance to impact in foot-pounds.

Type of Steel	%C	%Mn	%Ni	%Cr	%Mo	%V	A	B	C	D
Carbon	0.62	0.45	—	—	—	—	62.5 to 64	18	40.6	5
Chromium	0.49	0.53	—	0.60	—	—		18	56.5	66.5
Nickel	0.40	0.53	3.61	—	—	—		18.8	51.4	54.5
Cr, Ni	0.43	0.57	1.60	0.46	—	—		19.8	60.3	54
Cr, Mo	0.32	0.72	—	0.80	0.27	—		21	68	90
Cr, Mo	0.27	0.66	—	0.83	0.42	—	59.25-81.75	—	—	—
Cr, V	0.47	0.85	—	1.19	—	0.15	125	11	38.5	—
Cr, Mo	0.41	0.68	—	0.95	0.24	—		9	43.5	—
Cr, Ni, Mo	0.44	0.42	2.04	0.99	0.36	—	76	20.5	61	—
Cr, V, Mo	0.38	0.60	—	1.00	0.80	0.18	83	18.2	59.7	—
Carbon	0.1	0.45 annealed					15-17.5	30-40	55-65	—
Carbon	0.4	0.65 annealed					20-25	20-25	40-50	—
"	"	" heat-treated					22.5-50	5-25	25-50	—

The analytical determinations, given in a previous part of this paper, are now extended to include not only the metals present in the various alloy steels, but also occluded and combined gases. The following statements regarding the gases will be of interest:

A steel made by the basic Bessemer process cast into ingots and allowed to cool in a vacuum yielded gases equal to 2.3 cc. per gram, having the following volume percentage composition:

CH_4 0.2; O, 0.9; CO_2, 3.6; N, 12.7; CO, 30.5, and H, 52.2.

The nitrogen is also present combined as nitride; the determination of the latter is made by dissolving the sample in nitrogen-free HCl, which produces NH_4Cl, adding the solution to excess sodium hydroxide carefully freed from nitrogen, distilling off the NH_3 and Nesslerizing as in water analysis.

This method applied to the examination of specimens of iron, which in some cases were over a hundred years old with little signs of corrosion, showed the low nitride nitrogen content, 0.005-0.008 per cent.; tests made with more recent specimens exposed for 1-3 years showed, in cases of failure, 0.014 to 0.041 per cent. N, whereas specimens which showed little or no corrosion gave only 0.004-0.006 per cent. nitrogen, indicating that a high nitrogen content is at least one of the causes of corrosion. The explanations given for the absence of corrosion in some specimens of old iron may be reviewed: These specimens (1) represent a very pure grade of iron, (2) contain the metal copper in small quantity, and (3) contain a minimum quantity of combined nitrogen.

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FREE PUBLIC LECTURE COURSE

1923—1924

Philadelphia College of Pharmacy and Science

145 North Tenth Street.

The lectures will begin at 8.15 P. M.

First Lecture.   Thursday Evening, October 11, 1923.

SOME NEWS FROM OUTER DARKNESS.

By Henry Leffmann, A. M., M. D.

Lecturer on Research, Philadelphia College of Pharmacy and Science; Hon. Professor Organic Chemistry, Wagner Free Institute of Science, Etc.

Light is generally understood to be that form of energy which our eyes can detect, but it is now known that many similar forms exist that are invisible to us under ordinary conditions, but which produce striking effects and in some cases can be rendered visible. The lecture will present a brief explanation of these invisible forms and illustrate some of their actions, including the phenomena of fluorescence and phosphorescence.

Second Lecture.   Thursday Evening, October 25, 1923.

WIRE AND WIRELESS TELEPHONY.

By George Rosengarten, Ph. D.

Assistant Instructor in Physics, Philadelphia College of Pharmacy and Science.

The relation of the subject of wireless to the other fields of physical research will be discussed in order to clear the air of the "wonders" of the new means of communication. Sound waves and electro-magnetic waves—their similarity and difference, together with some fundamentals of sound and electricity; nature of

radiations of various wave lengths; radio transmission a development due to scientific research; the electron as a carrier of sound vibration.

Third Lecture.　　　　Thursday Evening, November 8, 1923.

THE GREAT AMERICAN RUBBER INDUSTRY.

By J. W. Sturmer, Phar. D.

Dean of Science, Philadelphia College of Pharmacy and Science.

By the aid of lantern slides and much illustrative material, the Story of Rubber will be told. The lecture will deal with the gathering of wild rubber in Central and South America, with the development and present importance of rubber plantations, with the processes of manufacture, and of vulcanizing, with particular reference to the newer advances in the procedure of making automobile tires, and of other rubber commodities which have come to be indispensable.

Fourth Lecture.　　　　Thursday Evening, November 22, 1923.

CHEMISTRY IN AND ABOUT THE HOME.

By Freeman P. Stroup, Ph. M.

Professor of Chemistry, Philadelphia College of Pharmacy and Science.

Chemistry and physics play a very much more important role in domestic life than most people realize. Without being conscious of it, the one who tends the fires, the genius who presides over the cook stove, and even the laundress, carry out processes which are generally essentially chemical and always involve the application of some one or more principles of physics. It is evident then, that the more the operator knows of the "why" of the things and the more nearly the work is done along scientific lines, the greater will be the degree of success attained. The lecturer will endeavor to present in non-technical language the principles underlying many everyday household operations, particularly of the kitchen, with the hope of being helpful to many who imagine that they "never could learn chemistry."

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Fifth Lecture   Thursday Evening, December 6, 1923.

WATER—AQUA—H₂O.

By Ralph R. Foran, P. D.

Assistant Professor of Technical and Analytical Chemistry, Philadelphia
College of Pharmacy and Science.

The ancient Greeks said that water was one of the four
elements or forms in which matter existed. We know now that
it is a chemical compound, but it is such a common substance
that we give it little attention and only realize its importance
in our scheme of existence when the supply is curtailed.

It is concerned in feast and famine, flood and drought, joy
and misery, life and death.

The lecture, which will be illustrated, will consider water in
its relationship to all of these, together with some of its scien-
tific aspects.

Sixth Lecture.   Thursday Evening, December 20, 1923.

IDIOSYNCRASIES, OR THE STORY OF A SNEEZE.

By Ivor Griffith, P. D., Ph. M.

Physiological Chemist, Stetson Hospital, Philadelphia, Assistant Professor
in Pharmacy, Philadelphia College of Pharmacy and Science, Editor
"American Journal of Pharmacy."

The subject of the lecture will be hay fever, "the American
Midsummer Madness"; its causative factors, modes of diagnosis
and treatment—how the modern chemist picks the culprit pollen
responsible for the sneezing fits and makes it turn about to cure
the sickened victim. Other protein antipathies will also be
discussed—Tabby, the cat, Dobbin the drowsy, or Fido the
faithful—often the innocent cause of persistent protein asthmas.
The lecture will be illustrated with lantern slides.

Seventh Lecture.   Thursday Evening, January 10, 1924.

RADIATIONS.

By David Wilbur Horn, Ph. D.

Professor of Physics and Physical Chemistry, Philadelphia College of
Pharmacy and Science, Professor of Inorganic Chemistry, Wagner
Free Institute of Science.

Discussion of cathode rays and positive rays—emission of
electricity by hot bodies. Photo electric effects. X-rays, alpha,
beta, and gamma rays. Radio-activity. The electron theory
of matter.

Eighth Lecture   Thursday Evening, January 24, 1924.

WHAT IS CHOCOLATE?

By E. Fullerton Cook, Ph. M.

Professor of Operative Pharmacy and Director of the Pharmaceutical
Laboratory, Philadelphia College of Pharmacy and Science.

A romantic story, linked with the Spanish Conquest of Central
America. This treasure has proved to be "living gold,"
one of the richest gifts of the Western Hemisphere to the
world.

It combines remarkable qualities—a food, a confection, a
cosmetic and a medicine.

Its modern cultivation, marketing and manufacturing, including
its important place in candy making, will be profusely
illustrated.

Ninth Lecture.   Thursday Evening, February 7, 1924.

SUGAR AS A MEDICINE, FOOD AND POISON.

By Horatio C. Wood, M. D.

Professor of Materia Medica, Philadelphia College of Pharmacy and
Science.

Although some of the European scientists in the first century
were familiar with a substance "resembling salt and tasting
like honey"—evidently our modern sugar—it was not for
ten centuries later that it acquired any common use in Europe.
In the 10th century it was introduced into medicine as a drug,

and a century later was employed as a condiment and food. In the 14th century it sold at a price which would be equivalent in modern times to about two dollars a pound.

Sugar is one of the most concentrated foods in common use. It is, however, entirely lacking in body-building properties, useful only for its energy value. Contrary to common belief, sugar is not especially easy to digest. These and many other interesting points will be fully discussed.

Tenth Lecture.   Thursday Evening, February 21, 1924.

SOCIAL INSECTS.

By Marin S. Dunn, A. M.

Assistant Professor of Botany, Philadelphia College of Pharmacy and Science.

The lecture will cover the following topics—the place of the insect in the animal kingdom, the White Ants (Termites), their origin, mode of living, etc., the Honey Bee, the Bumble Bee, the Social Wasp, the Ants, and a discussion on the instinct, intelligence and rationality, with examples. The lecture will be illustrated by charts, drawings, lantern slides and microscopic slides. Specimens will also be presented.

Eleventh Lecture.   Thursday Evening, March 6, 1924.

THE ROMANCE OF DRUGS.

Part I—Vegetable Drugs.

By Charles H. LaWall, Pharm. D., Sc. D.

Chemist to Food Bureau, Pennsylvania Department of Agriculture, Professor of Pharmacy, Philadelphia College of Pharmacy and Science.

Among the rarest and most valuable of the products of early commerce were vegetable substances used for remedial purposes. In many of these drugs the value was dependent upon superstition or occultism. Sometimes the medicinal property of a plant was determined by the fancied resemblance of one of its parts to an organ of the human body; others depended for their value upon imagined planetary influence and

"every herb had a star bespoke." Many owed their sole value to the secrecy and mystery attending their origin. Jesuit's Bark, Sacred Bitters, Ordeal Bean, Divine Plant of the Incas— these are titles which are reminiscent of the days when intrepid explorers brought back the products of strange lands; when kings paid enormous sums for the secret of some wonderful remedy which usually lost its efficacy along with its mystery.

The tale is one which lends itself well to illustration, and lantern slides and specimens will be shown.

Twelfth Lecture.   Thursday Evening, March 20, 1924.

SOMETHING ABOUT GASES.

By Frank X. Moerk, Ph. M.
Director of the Technical Chemistry Courses, Philadelphia College of
Pharmacy and Science.

There are many facts which the general public should know about gases, facts which have bearing upon the health and comfort of man. Air and ventilation, heating and illumina, tion, refrigeration and cold storage, preservation of foods, deterioration of foods, preparation of bread and cakes. The matter will be so presented that persons who have not had the advantage of a scientific education will be able to gain many interesting and important points.

Thirteenth Lecture.   Thursday Evening, April 3, 1924.

OUR MINUTE ENEMIES AND HOW TO ROUT THEM.

By Louis Gershenfeld, B. Sc., Ph. M.
Professor of Bacteriology, Philadelphia College of Pharmacy and
Science.

What are germs and germicides? What are the characteristics of the commonly found insect pests? What are insecticides and deodorants? What should be employed and how can it be used to best advantage so as to get rid of insects and germs? All of these questions are being constantly asked before and during house cleaning. Answers to these as well as other interesting data will be discussed in this lecture.

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Fourteenth Lecture.   Thursday Evening, April 17, 1924

THE DRUGS OF THE NORTH AMERICAN INDIAN.

By Heber W. Youngken, Ph. M., Ph. D.

Formerly Professor of Biology and Pharmacognosy and Director of the Botanical Gardens, Philadelphia College of Pharmacy and Science.

At Present Professor of Botany and Pharmacognosy in the Massachusetts College of Pharmacy.

A story of the drugs and medicines employed by the Indian tribes of North America from the time of its early settlement by the white man, the superstitions and ceremonies connected with their use and the influence of Indian ideas and methods upon the materia medica of the present day.

The lecture will be illustrated by an exhibit of Indian drugs.